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*Our Changing Conception of Human Nature,* by M. F. Ashley Montagu, Vol. III, No. 4, p. 221, line 24: *for* cultural, *read* natural.

# E R R A T A

*Page 29.* 3rd line of footnote: *for* 3,137 hectares *read* 3,137,000 hectares.

*Page 31.* 2nd line of footnote 2: *for* 1947-49 *read* 1947-48.

*Page 38.* 9th line: *for* of milk an average fat content *read* of milk with an average fat content.

*Page 38.* 17th line: *for* period of 356 days *read* period of 365 days.

*Page 40.* Table heading: *for* Results attesting Stations *read* Results at Testing Stations.

*Page 49.* 34th and 35th lines: *for* be given every to a promising *read* be given every year to a promising.

# SOCIETY IN THE GRIP OF SCIENCE[1]

*by*

H. A. SPOEHR

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It has become an established custom during the past few decades to recite and extol the great accomplishments of science and to describe the tremendous influence which science is exerting in our daily lives. The favoured phrase, "the impact of science on society", is heard on all sides and in all lands. But what we are just beginning to realize is that there is a mutual relationship between science and society. Science is affecting society, and society, though less obviously, is exerting an influence on science: It is true, of course, that scientific research is carried out by a very small number of people, and scientists constitute but a very slender section of society. Their influence is in no proportion to their numbers, though during the past few decades both their numbers and their influence in society have been growing at an almost fantastic rate. The developments of science have contributed so tremendously to the well-being and comforts of modern society that further advances in this direction have come to be taken for granted. Without completely realizing it, modern society has placed itself in the hands of science. Not without trepidation in some quarters, man is beginning to realize that his future, at least so far as it concerns his material well-being, is in the hands of scientists. As a matter of fact, science dominates modern life to a vastly greater extent than is commonly realized. And herein lies a responsibility for all scientists.

It is not necessary to recount in detail the practical accomplishments of science. Yet it is just because of the dominant position of science in our present-day society, because science is altering our lives almost daily and because the work of the scientists is being exploited for better or for worse on all sides, that the general public and the scientists are both in a considerable fog as to the mutual relationships of scientists and society. That these two groups, the professional scientist and the man in the street, are intimately related and definitively dependent upon each other in this modern world,

1. Address of the retiring president of the Pacific Division, American Association for the Advancement of Science, delivered at Oregon State College, 18 June 1952.

needs no special emphasis. It would seem, therefore, perfectly obvious that a better mutual understanding of each other is absolutely essential for the welfare of both. Yet the complexity of modern society, the tremendous specialization and fragmentation of science and the rate of change which characterizes modern life, makes such a mutual understanding extremely difficult.

One can but have compassion for the ordinary citizen, when one considers the confusion of ideas of a scientific nature which are thrown at him each day. Most of these ideas are quite beyond anything with which he comes in contact, removed from their normal context, and all too often given emphasis beyond their merit so far as his life is concerned. Many of these ideas he never hears of again, or if he does, they are in terms which he cannot recognize. They are usually discoveries or alterations within the complex minutiae of some aspect of science, with no calm evaluation of their true significance. It is hardly possible for the layman to understand how science has almost completely taken over our material existence. To him the picture presented is that of one startling discovery after another—a series of violent convulsions which successively ring out the old and ring in the new at an ever-increasing rate. It is little wonder that the great majority of people who live within the restricted spheres of ordinary life and who have little direct concern with these matters, become confused and indeed believe that science is getting out of hand. Their plaint of science is not one of too little and too late, but rather one of too much and too soon. Most of our people when their material wants are reasonably cared for are very conservative. True, they welcome the material conveniences wrought by science, but they are also aware of the disarrangements which accompany these innovations, or which, indeed, are occasioned by them. They like to think of themselves as progressive, but they find it difficult to make the necessary adjustments to change when they do not know what it is all about. What is too little understood is how science operates in our complex society. A masterly job has been done of selling to the public the products of applied science. But far too little has been done in enlightening the people on the role of science in the production of these products and services.

Science, so far as it affects the ordinary man, is usually presented as the result of some startling or revolutionary discovery. It is too rarely made clear that the application of science to the practical needs of man is a long and intricate evolutionary process. Too little emphasis has been placed on the fact that before science can find application or before science can be used at all, there must exist a body of basic knowledge to draw on. This knowledge is the foundation upon which all applications, be they industrial, agricultural, medical or what not, must rest. The degree to which this knowledge is sound determines in a large measure the workability or practicability of its applications. It is the amassing of this body of knowledge, its testing,

collation and ordering which is the main business of science. To the uninitiated this process is not particularly interesting, for the results are expressed in a language intelligible only to the specialist. Moreover, these generalizations are of necessity of a mutable character, since the very concepts used in interpreting observational data, such as "energy", "matter", "time", and "distance" are themselves subject to further experimental and rational analysis. Yet this gradually increasing body of knowledge constitutes the accumulated treasure of our modern world. From it primarily have arisen most of our modern comforts and fortunes, and it may well be the means of our survival.

The idea that there can be no application of science without a body of scientific knowledge to draw on, which to the professional scientist is so elementary and self-evident, appears to be one of the most difficult for the general layman to grasp. In no small measure the difficulty lies in the fact that the application of science is in *doing*; it is obvious, it is expressed in material things and in tangible results; whereas much of science, although also dealing primarily with material things, gives the summation of its experience largely in the form of mental concepts, which can be understood only after considerable special training. For convenience these concepts are expressed in a language which has little relation to that of ordinary life and which consequently is foreign and often repellent to the layman. This estrangement has been accentuated by the fact that the scientist is inclined to indulge in a form of intellectual snobbery, often quite unwittingly, through the indiscriminate use of his highfaluting language with his lay colleagues. Like all snobbery this has not made for a better mutual understanding. It is definitely the responsibility of the scientist to do his part to make intelligible to the public the role of fundamental scientific research for the welfare of society if he expects support for his work from this society.

Our statesmen and politicians have been most generous in making freely available to less favoured nations the results of American research through such means as the Point Four programme. It would be only a matter of prudence to allot a portion of this largess to the established U.S. agencies from whose stores of know-how these grants have been made. These stores of knowledge must be continuously replenished and extended. Only in this way can we maintain the leadership which is so essential to our survival. We should devote some millions of these altruistic dollars to investigations of the scientific aspects of population growth and human reproduction as they affect the over-all problem of human benefits to be derived from the applications of science to economic development.

Science has been remarkably successful in solving particular problems within well-defined fields and disciplines, and applying these discoveries to practical ends. Science and industry have also been very successful in convincing the public of the value and importance of technical education.

Where we have failed, especially in our general education, has been to see our problems whole—to see biology in relation to human sociology, to see engineering in relation to population problems, to see these in relation to natural resources, and so on. The natural tendency of science has been to isolate a problem from its more complex surroundings and reduce it to its simplest form. That has made for the fragmentation of science and has had some advantages. But it has also made it difficult for the specialist to see the problem as a whole. To understand the relation of some special contribution of science to broader human problem is precisely what is most needed for an appreciation of the value of science. The understanding of scientific problems as a whole on the part of scientists is today of the utmost importance. It is only as scientists themselves understand these broad aspects of their work and make a special educational effort to clarify these relationships that we can hope to attain a public comprehension of the role which science is playing in our social life.

There is another aspect of science which appears to be imperfectly understood by the public, namely, that the work of the scientist is never finished. That old story about the man who builds a better mousetrap having a path beaten to his door has a sequel which has rarely been mentioned. When a scientific discovery or invention has been brought to some practical application, the work of scientists is not finished, it has only just begun. Naïvely one might imagine, when it was found that petroleum can be used in place of whale oil in lamps, that certain strains of wheat are more disease-resistant than others, or that synthetic indigo can replace the natural product, that those jobs were done, and that forever after society would reap the benefits of these discoveries. Such is far from the true state of affairs so far as the scientist is concerned.

New undertakings and industries created by the applications of science not only give profitable employment to increasing numbers of workers, produce comforts and riches, but they demand an ever-increasing number of scientists to control and improve the products and processes concerned. This is a feature of the scientific era which is not sufficiently understood by the public. For example, the discovery of penicillin as a useful drug was made through the efforts of a very small group; the testing of its practicability entailed the efforts of a larger number of scientists; the large-scale development for the general use of the drug required a very considerably increased number; and the daily production, improvement and control of the product now involves certainly thousands of highly-trained people. The important point in all this is that without the constant, daily efforts of these scientifically-trained people this boon to humanity could not continue. The same principle applies to almost every development of material things and processes arising from scientific research. In agriculture, communication, transportation, health, building, means of defence, in fact wherever science has been applied, the

continuance of these activities requires the unceasing efforts of the scientist. Having started in this direction, the scientist has taken over, and society has put itself into the hands of the scientist. As a consequence, many of the most ordinary services, which most of us take for granted, such as a safe water supply, sanitary care of food-stuffs, the telephone, and fuel for our cars are dependent for continuous supply and operation upon the activities of scientists. And be it again noted, this is quite aside from the development of new processes and gadgets. It is mentioned here not for any self-aggrandizement on the part of scientists, but primarily to emphasize the responsibility to society which science has assumed, and especially to stress the accountability of scientists to the society which supports and trusts them.

There is a fundamental urge in Western civilization to develop, to expand, to make more efficient and effective man's control and use of the natural forces and resources which he is constantly discovering. It appears to be part of the evolutionary pattern of his being, of the succession of events and concepts, each growing out of that which precedes it, and not unlike organic evolution, characterized by ever greater complexity and specialization. Tempting as it is to analyse more particularly this phenomenon, we cannot attempt this now. But it is an indisputable fact, an irresistible trend, escape from which is only temporary, and, in oversimplified terms, appears to be one of Western civilization's reactions to unrestricted population growth. In brief, we are faced with this phenomenon of an ever more complex material existence which in a large measure is the result of applied science.

With these manifestations of the activities of scientists we are, of course, all familiar, and as we are becoming so dominantly a materialistic people they are also foremost in our national thinking. Yet there is another aspect of science which is perhaps not so evident or at least does not enter so much into popular discussions, but which is nevertheless a more fundamental and lasting influence. This is the intellectual or broadly cultural influence of science. As Merz has stated in his *History of European Thought in the Nineteenth Century*:[1] "Behind the panorama of external events and changes which history unfolds before our view there lies the hidden world of desires and motives, of passions and energies which accompany them; behind the busy scenes of Life lie the inner regions of Thought." Not only the vast general public but all too many scientists themselves pay little regard to the long and arduous struggle through which man has gone to attain freedom of thought. And this freedom of thought, this liberation from age-old superstitions and taboos, from authority and dictation, freedom from concepts of infallibility and inerrability in humans, is undoubtedly the greatest contribution which science has made to human progress. Such are the fruits of

1. John T. Merz, *A History of European Thought in the Nineteenth Century*, vol. I, W. Blackwood and Sons, Edinburgh and London, 1907.

the arduous struggles of the founders of modern science. Paul Sears[1] in his recent book on Charles Darwin puts it very tersely. He states: "Darwin had really hit the centre of the whole business—the right of the individual to trust his own eyes, and form his own judgments, tell the world his beliefs, and have the matter cleared by open trial and honest evidence. This was the essence of the Darwinian revolution." This freedom of thought, this independence from authority and this sovereignty of honest evidence constitute the foundation of modern science on which all of the real achievements are based. Of these achievements the most significant and valuable fruits are the great laws of nature. To apply the term law to these is in a way a misnomer and is much misunderstood by the unscientific, for these laws have not been promulgated through authority, nor are they decrees or edicts. They are the summation of experience. And as the product of experience they are subject to modification, to extension and to alteration, in short, to evolutionary change. But such changes are effected not by decree or injunction, but on the basis of new evidence; not necessarily by men in high places, but by any in the great army of scientists who can produce honest evidence.

The foundations of science, and especially the means by which they have been attained, constitute a bill of rights for the establishment of free thought throughout the modern world and have had a cultural influence far greater than is generally realized. Because of the more obvious and material fruits of scientific endeavour, these intellectual aspects have not been sufficiently emphasized; it is clearly the responsibility of scientists themselves to gain a better understanding of the historical and philosophical foundations on which their activities rest. Only on the basis of such an understanding can scientists impart to the public the real significance of science in our society. Much of the confusion concerning the role of science in modern society arises from the over-emphasis of the material fruits of science and disregard of the cultivation of the tree which bears these fruits.

We make adjustments to changes in our physical environment much more rapidly than we alter our habits of thought and attitudes of mind. We have accepted and welcomed the changes wrought in the material world through science, but in our modes of thought there remains much of the old savage. This is evidenced in many ways even in our relatively progressive American society, and may be illustrated by a few examples.

The true scientist welcomes criticism. He subjects his ideas and his work to self-criticism and usually invites and welcomes the objective criticism of his colleagues. Virtually the entire system of modern scientific publication of new information is based upon the critical review by professional col-

1. Paul B. Sears, *Charles Darwin—The Naturalist as a Cultural Force*, Charles Scribner's Sons, New York, 1950.

leagues. This does not mean that scientists live in a world of complete accord and altruism; far from it. Nor does is mean that scientists are not human, that they do not have all the human frailties, that there are not tyrants and autocrats among them. But scientists do not stand in awe of such authorities. They have a sufficiently objective view of their work to realize that if they are to gain the respect and confidence of their colleagues they must accept criticism and give criticism primarily on the basis of the evidence presented, and in the interest of arriving at the truth. As a nation we are peculiarly sensitive to criticism. In this respect we exhibit an immaturity which is quite out of accord with our age and place as a powerful nation in the world. If question is raised on matters of fundamental national policy all too frequently recourse is taken to vituperation and invective, degenerating into the complete disregard of the facts or issues. The phenomenon is all too familiar to demand elaboration and is growing to alarming proportions as a national failing.

A similar difference in mental attitude between the scientist in his own field and our attitude to general social problems concerns the matter of conformity. There is an old quip which defines a scientist as a man who is of a different opinion. While this impression has undoubtedly been much abused, it is true that scientists do not stand in awe of authority nor do they regard the established order within their domain as absolutely inviolable. If there were no differences of opinion there would be little progress. Scientists are essentially pioneers and progressives, and progress rarely goes hand in hand with conformity. New ideas and fresh relationships of more established ideas are the main concerns of science. It is inevitable that these evidences of change and progress should occasionally jolt the established order. Certainly there is nothing new in the altering or disarranging of the established order which is uniquely characteristic of science. The founding fathers of this nation were surely not conformists nor were the organizers of our great industries, which in a large measure have made the growth and survival of the nation possible. We tend to accept the beneficial consequences of all these pioneering efforts and petrify them into a static, set social structure. This rigour is the very antithesis of progress and eventually negates freedom.

We are experiencing in America today the pressure and influence of conformity as never before in our history. In almost every walk of life are the evidences of pressure to conform or to acquiesce to standard patterns or norms. In social behaviour, in dress, in food and drink, in attitudes towards friends and enemies and in outlook on life in general, we are experiencing greater standardization and less individuality. In a large measure this is due to the universal urge for material success and to the worship of the holy cow of security. Too rarely is it realized that security exacts its price. Life has always been an adventure and its greatest glories spring from its pursuit as an heroic enterprise. These potentialities of life must not be burnt on the altar of security.

If science in its broadest and most useful function to mankind is to survive, it must not conform to the popular belief that its main justification is the providing of immediate material welfare and security. These have their place in every society, and science willingly contributes to these ends. But scientists must raise their sights above immediate necessity and material social needs. They must educate their sponsors and society in general to an understanding of the function of science in discovering man's relation to his environment. This environment need no longer be regarded as a manifestation of some capricious supernatural being, but rather as the expression of universal scientific laws. Man's behaviour and control of himself in adjustment to these basic laws constitute conformity on a far sounder basis than conformity to man's whims and immediate material desires. And it is, moreover, of the very essence of science, as more sound information is collected through research, that these universal laws can be modified and amended.

It is also of the very essence of science that in order to amend, extend and modify our basic concepts of nature, science must be able to operate in an atmosphere of freedom. Now a great deal has been spoken and written, especially of late, on this question of freedom of scientific investigation, and many of these expressions have led to violently conflicting views of the place of the scientist in our social structure. That such should be the case is actually not surprising, because science is becoming so closely enmeshed in industry and so inextricably involved in political and international economy that it is frequently the dominant factor. In many of these relationships science has risen to play a prominent role with amazing rapidity. So rapid, in fact, has been the rise of science to this position that, on the one hand, administrators and political leaders have not had an opportunity to educate and adjust themselves to the principles underlying scientific thinking, and, on the other hand, scientists have not been trained for the social responsibilities which are becoming part of their lot. There was a time when there was a great gap, in terms of years, between a fundamental scientific discovery and its industrial application. Heinrich Hertz was spared the modern television programmes and Henri Becquerel the atomic bomb. Application moves at a much more rapid rate today. The so-called pure scientist looks back with longing to the more leisurely days of his untroubled predecessors of the nineteenth century, but at the same time pulls every string to get the financial support afforded him by the progress of the twentieth century. Like Lot's wife his mentality is thereby turning into a pillar of salt. With typical Gallic conciseness François Mauriac has said: "A people cannot be both the happiest and the most powerful in the world."

Science is rapidly becoming the most powerful influence, both intellectually and materially, in the modern world, and scientists are becoming a very troubled lot. It is definitely the function and responsibility of the scientists to determine whether the direction of this power shall reside in their own

hands, or whether the scientists shall become mere handmaidens to others who exploit these powers. In a large measure our present mode of life and level of civilization have been made possible through freedom of scientific thinking and action. It would, indeed, be an ironical turn of destiny if scientists surrendered this freedom and the opportunity to give man the full fruits of their labour for lack of enterprise and vision. It has been aptly said: ". . . there is only *one* evil: to deny one's freedom in order to evade the responsibility it implies".[1]

Now in spite of all that has been said to the effect that the scientist should have complete freedom, it must be conceded that there is no such thing as complete freedom in this modern world. There can be degrees of freedom or spheres of freedom. These are as much as we can hope for, and these are of the greatest importance. The freedom which the scientist cherishes so greatly and which is so essential to his fruitful labours is not something which comes of its own accord, as it were. Nor can this freedom be exacted or taken for granted in a society which for divers reasons is itself constantly losing much of its accustomed freedom. The scientist's freedom is something which must be intelligently nurtured, and it is his responsibility to see to it that the degree of freedom and the spheres of freedom he requires are understood and maintained by society. The scientist cannot expect that he should be treated with special consideration or as an especially favoured member of society without an understanding on the part of society of what this is all about. Such special privilege, without commensurate responsibility, would, in fact, be a most unwholesome situation in a democratic society, and in the end be apt to have most unfavourable reactions on the scientist's position.

Some of the confusion existing at the present time on this subject can be cleared up by determining or defining the purposes to which any given scientific endeavour is dedicated. It makes a great difference whether the purpose is one of applying science to definite practical ends or whether the purpose is the advancement of knowledge. It is no doubt true that under certain circumstances the line of demarcation between the two purposes may not be too sharply drawn, but as a general consideration there is a distinct difference in approach and point of view. A research which has as its expressed purpose the application of science to definite practical ends must of necessity depend for guidance on the authorities responsible for the practical objectives in hand. The administrators of industrial research have worked out these relationships with considerable success. The allowable degrees of freedom and the spheres of freedom within such undertakings seem to depend largely upon the nature of the practical projects and the human factors within the organization which such projects require.

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1. Alfred Stern, "What is Existentialism?", *Pacific Spectator*, 1950, vol. IV, p. 392.

In contrast with the attainment of definite practical ends is the scientific effort devoted to the consistent expansion of fundamental knowledge. This is a far more difficult process, because of the utterly unpredictable turns development of new knowledge may take and the uncertainty of its scope. It is, moerover, a process of intricate co-ordination in which the results of each scientist's labours must be adjusted and attuned to the results of others. He must weigh his new evidence in the light of what is known and combine or rearrange both to the extension of broader and sounder knowledge. This process cannot be supervised by a directing authority or central direction. It is a far too delicate and intuitive process. Some new evidence and discoveries may fall into a co-ordinating principle relatively easily; others, and probably the majority, require long periods of gestation for the ideas to become associated in their proper relationships. When a scientist is wrestling with such problems a part of his mind is on the solid ground of nature and in contact with all scientists who have gone before him, and another part of his mind is groping to make contact with concepts yet to be clarified, and thus to allow light to penetrate a little farther into the unknown. It is essentially a process of wrestling with his own conscience, of extracting the relevant from the extraneous, in short, of seeking the truth.

Within this sphere of endeavour a man must have complete freedom. Central direction and higher authority can contribute nothing to the mental processes involved; they may indeed stultify the entire creative effort. It is this aspect of creative scientific work which it is so essential for society to appreciate. It is quite as important in science as it is in the fields of the creative arts. Directed scientists and artists do not produce science and art, they are simply the slaves of imposed ideologies.

If scientists do not insist upon this freedom essential to the highest ideals of their calling, science and all the practical benefits to man arising therefrom will inevitably suffer. If scientists do not plan for the place which they are to occupy in our society, and for the role which science is to play in this society, this planning will by default fall into the hands of those who are eager for this power but know nothing about it, and the place of scientists will be little more than that of the eunuchs in the Sultan's palace. Scientists should not be satisfied to play the role of mere ghost writers.

As a matter of fact, scientists have enjoyed great freedom. It is primarily the result of the realization of the tremendous power inherent in science and because scientists have begun to throw their weight about a bit, that the question is being raised whether this freedom is always being used judiciously. Freedom for the pursuit of science is a trust. This trust carries a responsibility for the highest principles of human thought, the search for truth. The scientist must be accountable to society which grants the privileges under this trust. Like respect and honour, this freedom cannot be exacted or obtained on demand—it must be earned. Technical competency cannot be the

exclusive basis for awarding this freedom. Such competency offers no assurance of judgment or manners. Able scientists have been known to issue bad pronouncements, and all too often under the aegis of their scientific freedom and assumed immunity. These occurrences have long been the cause of many worrisome problems.

In our scientific organizations and associations we talk much about raising the status of the scientist. Everyone seems to have his own idea as to just what is meant thereby, whether it is financial, social or what. But in all of this, one aspect seems to have been too much neglected, and that is the ethical. For centuries other learned professions such as physicians, lawyers and clergymen have lived and worked under their codes of professional ethics. Such codes may not have been perfect, but they have at the very least emphasized the importance of the ethical aspect of these professions. They have served to demonstrate that mere proficiency in craftsmanship, extent of knowledge or attainment of academic degrees are in themselves not sufficient to warrant the respect and support of society. All these qualities are, needless to say, highly important, but over and above these are demanded qualities of character and ethical principles which have gone a long way in establishing confidence and esteem in the minds of the people. By contrast, scientists have been so engrossed in getting new results, in debating the minutiae of their subjects, in publishing tons of papers and in teaching an ever-growing number of students a constantly increasing mass of facts, that they have almost completely disregarded how their activities and lives fit into the society which supports them and of which they are a part.

Science can never become a profession, in the true sense of the word, until it gives more serious consideration to the ethical principles and social relations involved in its activities. If ethical standards are not developed by the scientists themselves and a high level of professional honour is not maintained by them, it is inevitable that rules and oaths will be imposed upon their activities from without. And this will be done by members of society wholly unfamiliar with the kind of freedom essential to the growth of science. The scientist's vision must reach beyond mere concern for the advancement of science. He should not take refuge in the subterfuge that science *per se* is amoral. Science gains its importance through its impact on society.

Every thoughtful person will realize that the ethical problems of science are exceedingly intricate and difficult, especially for those of us who have had little training and experience in dealing with the fundamental concepts concerned. It is so much easier and pleasanter to work in the laboratory than to think what it is all about. Obviously the scientist cannot be held responsible for every use that is made of his findings and discoveries. Almost every achievement of the human intellect in art, music, writing and even religion has at one time or another been prostituted for base and vulgar purposes. But this in itself is no excuse for shirking the broader responsibility, nor

does such shirking satisfy a man's sense of achievement. Sooner or later every thoughtful scientist is brought face to face with this responsibility. These ethical problems cannot be solved on the spur of the moment. Their sound elucidation demands much thought and soul searching; the answers are rarely there when most urgently desired. "The unexamined life is not worth living," said Socrates. It is entirely within the professional tradition of science that every aspect of life should be examined so that those who follow should have better understanding and richer life. Of late it has become the fashion to express concern for the survival of mankind as the result of the activities of scientists. Personally, I have little fear for its survival. But I believe we should have definite concern regarding the kind of people that do survive.

# THE CHALLENGE OF THE SPACESHIP

*by*

ARTHUR C. CLARKE

*This is a revised and up-to-date version of a paper read to the British Interplanetary Society in London on 5 October 1946, and published by the* Journal of the British Interplanetary Society *in December 1946. The author is a Fellow of the Royal Astronomical Society and has been chairman of the British Interplanetary Society since 1949. He has written several books on the subject, in particular* Interplanetary Flight *(London and New York 1950) and* The Exploration of Space *(London 1950 and New York 1951).*

*This article is, as its title states, a challenge. It describes the situation as it is now seen by one of the experts in the field and includes a number of predictions which may seem rash. They are made with enthusiasm, perhaps with too much enthusiasm—as were some previous predictions of Mr. Clarke. Yet it is none too soon to envisage now the possible implications of space travel on the social and political plane. In our age political and social institutions are constantly struggling to keep up with the rapid pace of scientific and technological change. Much of the harm that has been caused by the automatic machine or the aeroplane—to say nothing of the atomic bomb—could have been avoided if the consequences had been foreseen while the discoveries were still in the laboratory stage. This is the present situation with respect to space navigation. For this reason, Mr. Clarke's article is timely.*

A historian of the twenty-first century, looking back past our own age to the beginnings of human civilization, will be conscious of four great turning points which mark the end of one era and the dawn of a new and totally different mode of life. Two of these events are lost, probably forever, in the primeval night before history began. The invention of agriculture led to the founding of settled communities and gave man the leisure and social intercourse without which progress is impossible. The taming of fire made him virtually independent of climate and, most important of all, led to the working of metals and so set him upon the road of technological development—that road which was to lead, centuries later, to the steam engine, the Industrial Revolution, and the age of steel and petrol and surface transportation through which we are now passing.

The third revolution began, as all the world knows, in a squash-court in Chicago on 2 December 1942, when the first self-sustaining nuclear reaction was started by man. We are still too close to that cataclysmic event to see it in its true perspective, but we know that it will change our world, for better or for worse, almost beyond recognition. And we know too that it is linked with the fourth and in some ways greatest change of all—the crossing of space and the exploration of the other planets.

The first spaceships capable of reaching another world may still lie half a century ahead, but the giant rocket is already with us and will soon be carrying men to the limits of the atmosphere and beyond. Nor will it be many years before a guided missile reaches the moon and blazes the trail along which men will travel a generation later. In a report to the United States Secretary for War, dated 12 November 1945, General Arnold stated that the design of true spaceships was all but practicable today, and that research would bring them into being in the foreseeable future. Behind that statement one can see clearly the influence of the technicians from Peenemunde—many of them members of the pre-war German Rocket Society—who were captured by the Western Allies in the spring of 1945.

An attempt to construct a philosophy of astronautics is therefore far from premature: it is, if anything, a little belated. In the last few years we have seen the political and ethical chaos produced when a great technical development comes into a world which is unprepared for it. Perhaps it is already too late to redeem past follies: if so, this discussion is rather academic. But if our civilization is to have a future, then we must see that it does not repeat its earlier mistakes. I do not suggest—as some have done—that lawyers need start worrying immediately about the ownership of the moon, but the ownership of space will soon be a matter of acute practical importance. If country A fires experimental rockets across its neighbour B, what does B do? The air above B is admittedly its own property, but how far does that jurisdiction extend? There will have to be some equivalent of the three-mile limit; otherwise in the course of a day every country will, by virtue of the earth's rotation, lay claim to a large portion of the universe! This problem will be of grave concern in another decade, when long-range research projectiles begin to travel far outside the atmosphere with a supreme indifference to the geography beneath them.

## IDEALS AND MOTIVES

The ideals of astronautics are new, but the motives and impulses underlying them are as old as the human race. There was a time—not log ago—when those who advocated interplanetary travel were always being asked: "How?" Even before the war that question could be answered in general terms, but there had been no large-scale engineering achievement to support the claims put forward. It is amusing to recall that in those days—which now seem so remote—there were many people who refused to believe that a rocket could work in a vacuum or would ever be able to rise more than a few miles from the earth.

Today, the power of the rocket has been demonstrated, only too thoroughly. "How" is a question one seldom hears in discussions concerning

space-flight: the commoner query is now "Why?" And it is much more difficult to answer, for it involves the motives underlying all human conduct.

Some men compose music or spend their lives trying to catch and hold forever the last colours of the dying day, or a pattern of clouds that, through all eternity, will not come again. Others make voyages of exploration across the world, while some make equally momentous journeys in quiet studies with no more equipment than pencil and paper. If you asked these men the purpose of their music, their painting, their exploring or their mathematics, they would probably say that they hoped to increase the beauty or the knowledge in the world. That answer would be true, and yet misleading. Very few indeed would give the simpler, more fundamental reason that they had no choice in the matter—that what they did, they did because they must.

The urge to explore, to discover, to "follow knowledge like a sinking star", is a primary human impulse which needs, and can receive, no further justification than its own existence. The search for knowledge, said a modern Chinese philosopher, is a form of play. If this be true, then the spaceship, when it comes, will be the ultimate toy that may lead mankind from its cloistered nursery out into the playground of the stars.

However, it is not hard to think of entirely valid "practical" reasons why one should wish to cross space, and some of these we will discuss later. There is no doubt that eventually sheer necessity would bring about the conquest of the other planets. I do not believe that it is possible to have a virile, steadily-advancing culture limited to a single world, and taking the long-term view, we know that our earth will one day become uninhabitable.

In his book, *The Birth and Death of the Sun*,[1] the physicist George Gamow points out that before its evolution has finished, our sun will become 100 times as luminous as it is today. I am glad to see that he draws the obvious conclusion and visualizes the migration of humanity to the outer planets before our earth's oceans have begun to boil.

But the human race will not wait until it is kicked out. Long before the sun's radiation has shown any measurable increase, man will have explored all the solar system and, like a cautious bather testing the temperature of the sea, will be making breathless little forays into the abyss which separates him from the stars.

## CHEMICAL FUELS

To support my argument, I now have to develop some sort of time-scale. I do this with much reluctance, since prophecy is a dangerous and thankless

1. Viking Press, New York, 1940, and MacMillan, London, 1941.

business, frequently fatal to those who practise it. We have, however, learned by past experience that even the most extravagant forecast seldom overtakes the truth. H. G. Wells once wrote—and was no doubt laughed to scorn for his folly—that the aeroplane might have some influence upon warfare by 1950. Even Wells never imagined that by that date aircraft would not only have become of supreme importance but would have been challenged by still newer weapons.

The advances in rocket research since the 1940's have been phenomenal, but they have merely laid the foundations for what is still to come. Nevertheless, it is worth recording present achievements to fix the position of astronautics as it is today.

Nothing being known of rocket research in the Soviet Union, it would appear that the United States is far ahead of the rest of the world in this field. The U.S. armed forces and scientific services have made remarkable progress in upper atmosphere research. Heights of 385 kilometres and speeds of over 8,000 kilometres an hour have been attained by a "two-step" rocket fired from White Sands, main centre of American rocket activity. A large number of missiles, some more efficient and with higher ceilings than the original German V.2, have been developed. (For example the Viking, which though a single-stage rocket, should ultimately have a ceiling of over 300 kilometres.)

A great deal has been learned about the upper atmosphere by means of instruments carried in such rockets, which send their readings by radio to ground stations. In this way physical recovery of the rocket is unnecessary —though recently this has been achieved by means of special parachutes.

In addition, manned rocket vehicles, such as the Douglas Skyrocket—known to have flown at well over 2,000 kilometres an hour—have also been developed. These machines can hardly be called aircraft, since they operate at altitudes so great that conditions around them are almost the same as in (airless) space. As a result the new science of "space medicine" is already of practical importance, and the U.S. Air Force has set up a special department to deal with the problems involved. When these are overcome—and there is little question that they will be—the manned spaceships will be able to follow in the track of the robot missiles.

During the next decade, the techniques necessary to send small, radio-controlled rockets to the moon will become available. Such rockets would weigh about 50 tons at take-off and have a payload of a few kilogrammes. They could make astronomical reconnaissance flights of great scientific—and also psychological—importance.

There is no reason why such flights should not take place by 1960. The public, not realizing the problems still to be faced, will expect human beings to follow in a very short time. It will be disappointed. During the subsequent years there will be innumerable short-range flights beyond the

atmosphere by man-carrying ships reaching heights of a few thousand kilometres—and, as I have mentioned earlier, raising all sorts of petty legal problems. But if we have to rely on chemical fuels, it may well require at least 20 years of further experimenting before the first true spaceship lands upon the moon and returns to earth.

That brings us to the late 1970's. Any chemically-fuelled spaceships will be unwieldy, fabulously expensive machines with fuel consumptions measured by the thousand tons for a single voyage. Not more than one or two countries will be able to build them, and they will be of scientific value only. There will be no question, for a very long time, of colonization or of voyages to the other planets. But—and it is a very large but—any prophet would indeed be rash if he based his predictions upon the use of chemical fuels alone.

## ATOMIC POWER

Here, as in other fields, the great question-mark is atomic energy. In theory, a few kilogrammes of uranium could take a ship weighing 1,000 tons to the moon and back. In practice, we have a very long way to go before this can be done. At the moment one possible solution is that some form of enriched, high-temperature pile or reactor could be developed to accelerate a "working fluid" such as hydrogen, helium or some other gas of low molecular weight and so give a propulsive jet. Very great engineering difficulties will have to be overcome before this can be done, and an alternative solution is to use what has been called the "ion rocket". In this device charged particles would be accelerated by electric fields to produce the jet—the necessary fields being generated by nuclear energy. Such a scheme would have many advantages, but it could only operate in airless space—and it could only produce such low thrusts that it could not possibly lift a spaceship up from the earth's surface against the direct pull of gravity.

This is by no means a fundamental disadvantage, and indeed fits in very well with current ideas on astronautics. The fact that it is not possible for any spaceship to carry enough fuel for a voyage to another planet *and back* has long focused attention on what have been called "orbital techniques". Once a rocket is above the atmosphere and therefore no longer subject to air resistance, it becomes theoretically possible for it to turn itself into a sort of "artificial moon". All it need do to achieve this is to reach the necessary speed in horizontal flight, and from there on it will stay in its orbit without using any more power—just as the moon itself does. It could wait effortlessly until "tanker" rockets were sent up to refuel it: then, when its supplies had been replenished, it could continue on its way.

In this manner any interplanetary journey can be broken down into a number of stages, with refuelling between them, and this procedure is believed to be the key to space-flight. It seems likely that we may use the present-day "chemical" rockets to climb up from earth into the refuelling orbit, and then continue from there using atomic or "ion" rockets.

Atomic power is hardly likely to advance the conquest of space by more than 10 years, but it may make it practical almost from the beginning, which otherwise would certainly not have been the case. What is equally important, it will mean that the whole solar system, and not merely the moon, will be immediately accessible to man. It requires little more power to reach the planets than it does to go to the moon, but the most economical voyages involve months or even years of free "coasting" along orbits curving halfway round the sun. With atomic power these journeys could be cut to a fraction of the time. For example, the "cheapest" journey to Mars —as far as fuel is concerned—lasts 258 days. With an atomic ship, travelling by a more direct route at quite a moderate speed, it need take only a few weeks.

The last quarter of this century will be an age of exploration such as man has never before known. By the year 2000 most of the major bodies in the solar system will probably have been reached, but it will take centuries to examine them all in any detail. Those who seem to think that the moon is the goal of interplanetary travel should remember that the solar system contains eight other planets, at least 30 moons, and some thousands of asteroids. The total area of the major bodies is about 250 times that of earth, though the four giant planets probably do not possess stable surfaces on which landings could be made. Nevertheless, that still leaves an area 10 times as great as all the land surface of the earth.

This, then, is the future which lies before us, if our civilization survives the diseases of its childhood. It is a future which some may find terrifying, as no doubt our ancestors found the hostile emptiness of the great oceans. But the men who built our world crossed those oceans and overcame those fears. If we fail before the same test, our race will have begun its slide into decadence. Remember, too, that when the great explorers of the past set sail into the unknown they said goodbye for years to their homes and everything they knew. Our children will face no such loneliness. When they are among the outermost planets, when the earth is lost in the glare of the sun and the sun itself is no more then the brightest of the stars, they will still be able to hear its voice and to send their own words in a few hours back to the world of men.

## EFFECTS ON THE SCIENCES

Let us now consider the effects which interplanetary travel must have upon human institutions and ideas. The most obvious and direct result of the crossing of space will be a revolution in almost all branches of science. I shall not attempt to list more than a few of the discoveries we may make when we can set up research stations and observatories upon the other planets. One can never predict the outcome of any scientific investigation, and the greatest discoveries of all—the ones which will most influence human life—may come from sciences as yet unborn.

Astronomy and physics will, of course, be the fields of knowledge most immediately affected. In both these sciences there are whole areas where resarch has come to a dead end, or has never even started, because our terrestrial environment makes it impossible.

The atmosphere, which on a clear night looks so transparent, is in reality a coloured filter blocking all rays beyond the ultra-violet. Even in the visible spectrum the light that finally struggles through the shifting strata above our heads is so distorted that the images it carries dance and tremble in the field or the telescope.

An observatory on the moon, working with quite small instruments, would be many times as effective as one on earth. Far greater magnifications could be employed, and far longer exposures used. In addition, the low gravity would make relatively simple the building of larger telescopes than have ever been constructed on this planet.

In physics and chemistry, access to vacua of unlimited extent will open up quite new fields of investigation. The electronic scientist may well look forward to the day when he can build radio tubes a kilometre long, if he wishes, merely by setting up his electrodes in the open! We may learn more about gravity when we can escape partially or wholly from its influence.

The prospect of building stations in space, circling the earth like tiny moons in orbits beyond the atmosphere, is one that has a peculiar fascination. Such stations were first proposed by the Germans as refuelling depots for spaceships, but even if that need never arises they would have other most important applications. Meteorological observatories in space could see at a glance the weather over half the planet, could watch in detail the movement of storms and rain areas. The wonderful photographs of the earth from V.2 rockets give a hint of what may be done in this direction. Indeed, really accurate forecasting may have to wait until we get the meteorologists out into space.

The space station has one other application of the greatest importance, for it provides perhaps the only means of worldwide television broadcasting. As is well known, the reliable range of a television transmitter extends barely beyond the horizon. A dozen stations at least would be needed to cover

completely a country as small as Great Britain, and continental or world services would be completely out of the question. Yet three relay stations circling the earth could provide a steady, reliable service from pole to pole with no more power output than a single present-day station.

## EFFECTS ON HUMAN THOUGHT

However, the first direct results of astronautics may be less important than its indirect consequences. This has proved true in the past of many great scientific achievements. Copernican astronomy, Darwin's theory of evolution, Freudian psychology—these had few immediate practical results, but their effect on human thought was tremendous.

We may expect the same of astronautics. With the expansion of the world's mental horizons may come one of the greatest outbursts of creative activity ever known. The parallel with the Renaissance, with its great flowering of the arts and sciences, is very suggestive. "In human records," wrote the anthropologist J. D. Unwin, "there is no trace of any display of productive energy which has not been preceded by a display of expansive energy. Although the two kinds of energy must be carefully distinguished, in the past they have been . . . united in the sense that one has developed out of the other". Unwin continues with this quotation from Sir James Frazer: "Intellectual progress, which reveals itself in the growth of art and science . . . receives an immense impetus from conquest and empire." Interplanetary travel is now the only form of "conquest and empire" compatible with civilization. Without it, the human mind, compelled to circle forever in its planetary goldfish bowl, must eventually stagnate.

We all know the narrow, limited type of mind which is interested in nothing beyond its town or village, and bases its judgments on parochial standards. We are slowly—perhaps too slowly—evolving from that mentality towards a world outlook. Few things will do more to accelerate that evolution than the conquest of space. It is not easy to see how the more extreme forms of nationalism can long survive when men begin to see the earth in its true perspective as a single small globe among the stars.

There is, of course, the possibility that as soon as space is crossed all the great powers will join in a race to claim as much territory as their ships can reach. Some American writers have even suggested, more or less seriously, that for its own protection the United States must occupy the moon to prevent it being used as a launching site for atomic rockets. Fantastic though such remarks may seem today, they represent a danger which it would be unwise to ignore. The menace of interplanetary imperialism can be overcome only by worldwide technical and political agreements well in advance of the actual

event, and these will require continual pressure and guidance from the organizations which have studied the subject.

The solar system is rather a large place, though whether it will be large enough for so quarrelsome an animal as *Homo sapiens* remains to be seen. But it is surely reasonable to hope that the crossing of space will have a considerable effect in reducing the psychological pressures and tensions of our present world. Much depends, of course, on the habitability of the other planets. It is not likely that very large populations will, at least for many centuries, be able to subsist outside the earth. There may be no worlds in the solar system upon which men can live without mechanical aids, and some of the greatest achievements of future engineering will be concerned with shaping hostile environments to human needs.

We must not, however, commit the too common mistake of equating mere physical expansion, or even increasing scientific knowledge, with "progress" —however that may be defined. Only little minds are impressed by sheer size and number. There would be no virtue in possessing the universe if it brought neither wisdom nor happiness. Yet possess it we must, at least in spirit, if we are ever to answer the questions that men have asked in vain since history began.

Perhaps analogy will make my meaning clearer. Picture a small island inhabited by a race which has not yet learned the art of making ships. Looking out across the ocean this people can see many other islands, some of them much the same as its own but most of them clearly very different. From some of these islands, it is rumoured, the smoke of fires has been seen ascending—though whether those fires are the work of men, no one can say.

Now these islanders are very thoughtful people and writers of many books with such resounding titles as: *The Nature of the Universe, The Meaning of Life, Mind and Reality,* and so on. Whilst admiring their enterprise, I do not think we should take their conclusions very seriously—at least until they have gone a little further afield than their own coral reef. As Robert Bridges wrote:

> Wisdom will repudiate thee, if thou think to enquire
> WHY things are as they are or whence they came: thy task
> Is first to learn WHAT IS.

That task the human race can scarcely begin to undertake while it is still earthbound.

Every thoughtful man has asked himself: is our race the only intelligence in the universe, or are there other, perhaps far higher, forms of life elsewhere? There can be few questions more important than this, for upon its outcome may depend all philosophy—yes, and all religion too.

The first discovery of planets revolving round other suns, which was made

in the United States in 1942, has changed all ideas of the plurality of worlds. Planets are far commoner than we had believed: there may be thousands of millions in this galaxy alone. Few men today would care to argue that the earth must be the only abode of life in the whole of space.

It is true—it is even likely—that we may encounter no other intelligence in the solar system. That contact may have to wait for the day, perhaps ages hence, when we can reach the stars. But sooner or later it must come.

There have been many portrayals in literature of these fateful meetings. Most science-fiction writers, with characteristic lack of imagination, have used them as an excuse for stories of conflict and violence indistinguishable from those which stain the pages of our own history. Such an attitude shows a complete misunderstanding of the factors involved.

Remember the penny and the postage stamp which Sir James Jeans in the *Mysterious Universe*[1] balanced on Cleopatra's needle. The obelisk represented the age of the world, the penny the whole duration of man's existence, and the stamp the length of time in which he has been slightly civilized. The period during which life will be possible on earth corresponds to a further column of stamps hundreds of metres—perhaps a kilometre—in height.

Thinking of this picture, we see how infinitely improbable it is that the question of interplanetary warfare can ever arise. Any races we encounter will almost certainly be superhuman or subhuman—more likely the former, since ours must surely be one of the youngest cultures in the universe. Only if we score a bull's eye on that one stamp in the kilometre-high column will we meet a race at a level of technical development sufficiently near our own for warfare to be possible. If ships from the earth ever set out to conquer other worlds they may find themselves, at the end of their journeys, in the position of painted war-canoes drawing slowly into New York Harbour.

But if the universe does hold species so greatly in advance of our own, then why have they never visited the earth? There is one very simple answer to this question. Let us suppose that such races exist: let us even suppose that, never having heard of Einstein, they can pass from one end of the galaxy to the other as quickly as they wish.

That will help them less than one might think. In 10 minutes, a man may walk along a beach—but in his whole lifetime he could not examine every grain of sand upon it. For all that we know, there may be fleets of survey ships diligently charting and recharting the universe. Even making the most optimistic assumptions, they could scarcely have visited our world in the few thousand years of recorded history.

Perhaps, even at this moment, there lies in some rather extensive filing system a complete report on this planet, with maps which to us would look

1. Cambridge University Press, and MacMillan, New York, 1930.

distorted but still recognizable. That report would show that though the earth was teeming with life, it had no dominant species. However, certain social insects showed considerable promise, and the file might end with the note: "Intelligence may be emerging on this planet. Suggest that intervals between surveys be reduced to a million years."

Very well, you ask—suppose we encounter beings who judge, condemn and execute us as dispassionately, and with as little effort, as we spray a pool of mosquito larvae with DDT? I must admit that the possibility exists, and the logical answer—that their reasons will no doubt be excellent—is somewhat lacking in appeal. However, this prospect seems remote. I do not believe that any culture can advance, for more than a few centuries at a time, on a technological front alone. Morals and ethics must not lag behind science, otherwise the social system will breed poisons which will cause its own destruction. I believe therefore that with superhuman knowledge must go equally great compassion and tolerance. In this I may be utterly wrong: the future may yet belong to forces which we should call cruel and evil. Whatever we may hope, we cannot be certain that human aspirations and ideals have universal validity. This we can discover in one way only, and the philosophical mind will be willing to pay the price of knowledge.

I have mentioned before how limited our picture of the universe must be so long as we are confined to this earth alone. But the story does not end there. Our impressions of reality are determined, perhaps more than we imagine, by the senses through which we make contact with the external world. How utterly different our cosmologies would have been had nature economized with us, as she has done with other creatures, and given us eyes incapable of seeing the stars! Yet how pitiably limited are the eyes we do possess, tuned as they are to a single octave in an endless spectrum. The world in which we live is drenched with invisible radiations, from the microwaves which we have just discovered coming from sun and stars, to the cosmic rays whose origin is still one of the prime mysteries of modern physics. These things we have discovered within the last generation, and we cannot guess what still lies beneath the threshold of the senses—though recent discoveries in paranormal psychology hint that the search may be only beginning.

The races of other worlds will have senses and philosophies very different from our own. To recall Plato's famous analogy, we are prisoners in a cave, gathering our impression of the outside world from shadows thrown upon the walls. We may never escape to reach that outer reality, but one day we may hope to meet other prisoners in adjoining caves, where the shadows may be very different and where we may learn far more than we could ever do by our own unaided efforts.

These are deep waters, and it is time to turn back to the shore, to leave the distant dream for the present reality of fuels and motors, of combustion-chamber pressures and servo-mechanisms. Yet I make no apology for

discussing these remote vistas at some length, if only to show the triviality of that point of view which regards interplanetary travel as a schoolboy adventure of no more real value than the scaling of some hitherto inaccessible mountain. The adventure is there, it is true, and that is good in itself—but it is only a small part of a much greater whole.

Not so short-sighted, but equally false, is the view expressed by the Oxford thinker C. S. Lewis, who has written of would-be astronauts in this unflattering fashion: "The destruction or enslavement of other species in the universe, if such there are, is to these minds a welcome corollary." Mr. Lewis's ideas appear to have been culled in the cloisters of Magdalen College from a perusal of the pages of "Staggering Stories"—not, I think, evidence on which any jury would convict. Yet in case there are any to whom this prospect still appeals, I would point out that empires, like atomic bombs, are self-liquidating assets. Dominance by force leads to revolution, which in the long run, even if indirectly, must be successful. Humane government leads eventually to self-determination and equality, as the classic case of the British Empire has shown. Commonwealth alone can be stable and enduring, but empires must always contain the seeds of their own dissolution.

The desire to give a comprehensive picture of the outcome of astronautics has compelled me to range—not unwillingly—over an enormous field. However, I do not wish anyone to think that the possibilities we have been discussing need come in this century, or the next, or the next. . . . Yet any of them may arise, at any time, as soon as the first ships begin to leave the earth. Man's first contact with other intelligent races may lie as far away in time as the building of the Pyramids—or it may be as near as the discovery of X-rays.

## INTERSTELLAR TRAVEL

Of this, at least, we may be fairly certain: barring accidents—the most obvious of which I need not specify—the exploration of the planets will be in full swing as this century draws to its close. To examine them in any detail, and to exploit their possibilities fully, will take hundreds of years. But man being what he is, when his first ship circles down into the frozen wastes of Pluto, his mind will already be bridging the gulf still lying between him and the stars.

Interplanetary distances are a million times as great as those to which we are accustomed in everyday life, but interstellar distances are a million-fold greater still. Before them even light is a hopeless laggard, taking years to pass from one star to its neighbour. How man will face this stupendous challenge I do not know: but face it one day he will. Professor Bernal was, I believe, the first to suggest that one solution might lie in the use of artificial

planets, little self-contained worlds embarking upon journeys which would last for generations. Olaf Stapledon has expanded this theme in *Star Maker,* one of the greatest of his fantasies, but the thought of these tiny bubbles of life, creeping from star to star on their age-long journeys, carrying whole populations doomed never to set foot upon any planet, never to know the passage of the seasons or even the interchange of night and day, is one from which we might well recoil in horror. However, those who would make such journeys would have outlooks very different from our own and we cannot judge their minds by our standards.

These speculations, intriguing though they are, will hardly concern mankind in this century. We may, I think, expect that it will be at least years before confinement to the solar system produces very marked signs of claustrophobia.

## CONCLUSIONS

Our survey is now finished. We have gone as far as is possible, at this moment of time, in trying to assess the impact of astronautics upon human affairs. I am not unmindful of the fact that 50 years from now, instead of preparing for the conquest of the outer planets, our grandchildren may be dispossessed savages clinging to the fertile oases in a radio-active wilderness. Yet we must keep the problems of today in their true proportions. They are of vital—indeed of supreme—importance, since they can destroy our civilization and slay the future before its birth. But if we survive them, they will pass into history and the time will come when they will be as little remembered as the causes of the Punic Wars. The crossing of space—even the sense of its imminent achievement in the years before it comes—may do much to turn men's minds outwards and away from their present tribal squabbles. In this sense the rocket, far from being one of the destroyers of civilization, may provide the safety-valve that is needed to preserve it.

This point may be important. By providing an outlet for man's exuberant and adolescent energies, astronautics may make a truly vital contribution to the problems of the present world. Space-flight does not even have to be achieved for this to happen. As soon as there is a general belief in its possibility, that belief will begin to colour men's psychological outlook. In many ways, the very dynamic qualities of astronautics are in tune with the restless expansive spirit of our age.

I have tried to show that the future development of mankind, on the spiritual no less than the material plane, is bound up with the conquest of space. To what may be called—using the words in the widest possible sense —the liberal scientific mind, I believe these arguments to be unanswerable. The only real criticism that may be raised against them is the quantitative

one that the world is not yet ready for such changes. It is hard not to sympathize with this view, which may be correct, but I have given my reasons for thinking otherwise.

The future of which I have spoken is now being shaped by men working with slide-rules in quiet offices, and by men taking instrument readings amid the savage roar of harnessed jets. Some are engineers, some are dreamers —but many are both. The time will come when they can say with T. E. Lawrence: "All men dream; but not equally. Those who dream by night in the dusty recesses of their minds wake in the day to find that it was vanity: but the dreamers of the day are dangerous men, for they may act their dream with open eyes, to make it possible."

Thus it has always been in the past, for our civilization is no more than the sum of all the dreams that earlier ages have brought to fulfilment. And so it must always be, for if men cease to dream, if they turn their backs upon the wonder of the universe, the story of our race will be coming to an end.

# REPORTS AND DOCUMENTS

## NATIONAL DEVELOPMENT BASED ON SCIENCE: THE CASE OF DENMARK,

by Borge Michelsen.

*Borge Michelsen was for some years in charge of the programme for teaching and dissemination of science at Unesco. In 1952 he resumed his work as a Danish science editor.*

The story of modern Denmark begins a little after the middle of the nineteenth century when Denmark underwent a kind of shock treatment. I am not, as those familiar with the history of Denmark might imagine, thinking of the 1864 war with Prussia and Austria, when the provinces of Holstein, Lauenburg and Schlesvig[1] were lost to Denmark, thus reducing its area by 30 per cent and its population by 40 per cent. Denmark survived—only to find itself under the deadly threat of economic brankruptcy.

Denmark has no coal or important mineral deposits, and in the middle of the nineteenth century it was a predominantly agricultural country with grain as its chief export. Danish grain had sold well for many years when, towards the end of the 1860's and the beginning of the 1870's, competition from Siberia and overseas countries, especially the U.S.A., began to make itself felt. The railways had opened up the American continent and given access to enormous fertile areas, and American farmers were shipping grain to Europe in ever increasing quantities at constantly falling prices.

Some countries, such as Germany and Sweden, adopted corn laws, thus making it possible for their farmers to obtain on the home market prices higher than those on the world market. For Denmark, however, such a policy would have been detrimental to urban dwellers without benefiting the farmers to any marked extent. The grain consumption in Denmark was only a small part of the country's production, and no Danish law could help the farmers on the world market.

Denmark was forced to the wall. It had to export or die and it could no longer export grain.

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1. In 1951 Denmark had 4,288,700 inhabitants. They live in an area about twice the size of Wales or the state of Massachusetts. Of Denmark's total area of about 4,230,000 hectares, some 3,137 hectares is agricultural land and 390,000 hectares forest. Horticulture accounts for 90,000 hectares including 32,000 hectares of market gardens and commercial orchards. The unproductive area (moor and heath, swamps and bogs, sand dunes, etc.) is about 350,000 hectares, having declined during the preceding 50 years by approximately 300,000 hectares. In the same period agricultural land of about the same area was diverted to other uses—buildings, roads, parks, etc. Following a plebiscite after World War I, the northern part of Schlesvig, viz. 320,000 hectares with 164,500 inhabitants, was returned to Denmark.

## TURNING COWS, PIGS AND HENS INTO FACTORIES

Denmark solved the problem by turning a somersault. From a grain-exporting country it turned itself into a grain-importing country almost overnight. Around 1870 Denmark was still exporting about 300,000 tons of grain annually; in 1880 it was importing 140,000 tons besides other feed-stuffs. In 1900 the import of feed-stuffs was 600,000 tons, in 1931 it was 1,870,000 tons (mainly oil cakes and coarse grains). At the same time Denmark speeded up its production of grain, clover, grass, root crops, etc. The annual yield, which in the years 1875-79 was 38 million crop units,[1] is now about 130 million.

Most of the import and home production was used for the feeding of an increasing number of pigs, hens and cows. These, so to speak, became factories turning raw materials into refined articles: bacon, eggs, butter, and these naturally commanded higher prices than the raw materials.

The switch-over was carried out after a market analysis had indicated the probability of a growing demand for animal products among the workers and middle classes in the industrial countries, especially in England, where living conditions had gradually improved during the nineteenth century.

The new means of transport that had brought the threat of destruction to Denmark were skilfully utilized in starting the country on the new road that was not only to give Denmark a prominent position as a purveyor of bacon, butter and eggs to the world market, but also to make it possible for its industry to build itself up. It soon proved that Danish industry was often able to import its raw materials by sea as cheaply as industries in countries endowed with raw materials were able to get them by rail within their own frontiers.

Danish export of eggs began in a small way with occasional shipments to Norway, and when a regular steamship service with Britain was established in 1865, export of eggs to that country was commenced. Exports increased, especially after 1895 when a considerable improvement in quality was achieved, and from 1933 until the outbreak or World War II Denmark was the biggest exporter of eggs in the world. Total exports in 1939 were 103,000 metric tons.

Before the war with Prussia a considerable number of pigs were being sent to Hamburg for curing in bacon factories operated there by London firms. The first Danish factories were established after the war and their goods were sent by the same boats as the first egg exports. In 1870 a weekly sailing from Copenhagen to Newcastle added to the facilities available for exporting to Britain, and in 1875 the route from Esbjerg to Harwich was opened. Steadily and surely Danish bacon improved its standing in the British market until, in about 1930, over 60 per cent of all British imports of bacon came from Denmark.

A small quantity of Danish butter was already exported before the "grain wave" swept over Europe. After Danish butter had been awarded first prize at the International Dairy Exhibition in London in 1879, a rapid rise in production and exports made it increasingly important in the world butter

1. One crop unit is the equivalent of 100 feed units, viz. 100 kg. of barley or 100 kg. of rye or 100 kg. of wheat or 120 kg. of oats or 100 kg. of dry matter in potatoes or 110 kg. of dry matter in roots or 210 kg. of hay or 400-500 kg. of straw.

trade. Between the two world wars Denmark was the world's largest exporter of butter, accounting for 25 per cent of total exports.

Butter, bacon and eggs opened the way in the world market for many other Danish products, and this increase in exports contributed largely to the increase of the national income from 1870 onwards.

| *Year* | *Population* | *Average annual wage of all workers in kroner* | *National income million kroner* |
|---|---|---|---|
| 1870 | 1,784,741 | 500 | 500 |
| 1905 | 2,574,000 | 900 | 1,400 |
| 1930 | 3,550,656 | 2,200 | 5,000 |
| 1947 | 4,123,600 | 5,000 | 15,000 |

Consumers price ratio 1870-1947 = 1:3. By "all workers" is meant all workers in handicrafts, industry, commerce and agriculture.

## HOW IT WAS DONE

A few words must be said about the machinery which effected the switch-over from a grain-exporting to a grain-importing and grain-refining country. Part of this machinery already existed when the decision was taken, and the rest was built up during the process of transition.

### *Agricultural Associations*

Up to about 1840 members of the few existing agricultural associations[1] were mainly patriotic philanthropists. But from then on more and more farmers began to take part in the work of the existing agricultural associations and to form new ones. Today, Denmark has 70 unions of large farmers with 1,500 members, 138 farmers' associations with a membership of 142,000, and 1,283 smallholders' associations with 110,000 members.[2] The farmers' associations have a central organization, the Federation of Danish Farmers' Associations. The corresponding body of the smallholders is the Federation of Danish Smallholders' Associations.

### *The Agricultural College*

In 1845 the first farmers' conference was held. In 1858 the Royal Veterinary and Agricultural College[3] (here called Agricultural College) developed out

1. The first agricultural society to be formed was the Royal Agricultural Society (1769). Its aim was, and still is, the creation of active interest in Danish economic life with a special view to agriculture.
2. In addition there were 325 Domestic Economy Associations with 79,000 members and 72 Young Farmers' Clubs with 8,000 members. In 1947-49, 20,000 young farm workers were given training and instruction on the farms and took part in such competitions as ploughing, sowing, milking, stockman's work, care of animals, animal judging and cultivation of small pieces of land.
3. Veterinary training had been given at the Royal Veterinary School from 1773. At the beginning of the nineteenth century agricultural instruction came under the University of Copenhagen, later under the Technical College. The scope of the Royal Veterinary and Agricultural College was gradually extended to six faculties. From 1858 advanced instruction was given in veterinary science, agriculture and surveying; from 1863 horticulture and forestry were included; and from 1921 dairying.

of courses hitherto given at the Technical College. Several technical advances were made in this period. For example, ploughs were improved, crop rotation was better planned, draining and ditching were increasingly adopted, and, after 1860, improvements began in livestock husbandry.

*The Folk High Schools*

General education, founded by the Education Act of 1814 which introduced free and compulsory elementary education, though not yet satisfactory in the 1840's and 1850's, was gradually improving.

After 1844, when the first Folk High School was established, the rural youth increasingly adopted this form of adult education. In 1869, the number of Folk High Schools was 50, and today there are 58. Courses are state-subsidized and usually divided between winter courses of five months' duration for young men and summer courses of three months' for young women. Opinion differs about the extent to which the Folk High Schools conditioned the rise of the Danish co-operative movement, but that they were of great importance to it has never been disputed.

*Agricultural Schools*

While the Folk High Schools were trying—in the words of a High School leader—to give rural youth "a right attitude towards life", agricultural schools were started to give a right attitude towards agriculture to those who either could not afford or did not want to enlist for higher education at the Agricultural College in Copenhagen. The first agricultural school, started in 1867, was soon followed by others, and today there are 29 agricultural, dairy and horticultural schools.[1] Courses at these schools are of five-nine month's duration during which the students stay at the schools, as do the students at the Folk High School. These courses are considered supplementary to the practical training the young people receive while serving their apprenticeship on various farms.

*Agricultural Advisory Officers*

Short 10-day courses on every kind of agricultural topic are constantly being arranged by the agricultural advisory officers employed by the farmers' and smallholders' associations.

The first agricultural advisory officer was appointed by the Royal Agricultural Society in 1860, and the first local farmers' association appointed one in 1870. Now there are some 600 with 300 scientifically trained assistants. More details about their work will be given later.

*Co-operatives*

It has been an important feature of the programmes of co-operative movements in many countries that part of the profits be set aside for educational and other work of an idealistic character. The first Danish co-operative societies were also of this mixed character pursuing both economic and

1. In addition there are 28 Domestic Economy Schools.

idealistic aims. But as the agricultural co-operative movement gradually developed, the idealistic aims gave way more and more to the economic objectives. It is true that the societies preserved their idealistic character as far as programme and working methods were concerned, but they no longer undertook direct education.

The first Danish producers' co-operative was formed in response to the need for increasing butter exports. Until the 1860's every farm was producing its own butter, and only the estates could count on always having sufficient fresh milk at their disposal. The small farms[1] had to wait until sufficient milk had accumulated. During the 1860's some "joint dairies" (privately-owned dairies buying milk from a group of farmers) were established. They did not all live up to expectations, and when in the 1870's N. J. Fjord of the Agricultural College started making dairying a science, and the Danish engineer L. C. Nielsen invented the centrifugal separator in 1878, discussions began on possible new types of dairies.

The co-operative principle in dairying was first applied by a group of farmers in Jutland, who in the spring of 1882 started the Hjedding Co-operative Dairy. They set up a form of organization which was to become the pattern for all future co-operative dairies. Some of the guiding principles were: the members were to own the dairy in common; the capital to erect the building and buy the equipment was to be raised by a loan against the security of the members' real property, and the members were to be jointly responsible; any profit was to be divided according to the amount (later on was added: *and* quality) of milk delivered; the democratic principle was maintained by the rule that each member was to have only one vote at the general assembly irrespective of the number of cows he owned.

The idea spread like wildfire. By 1886 there were 176 co-operative dairies; during 1887-88 no less than 300 were formed; by 1900 there were 942, and in 1949 there were 1,321.

Other branches of agriculture soon followed the example set by the farmers at Hjedding, and it was not long before Denmark was transformed into "the country of agricultural co-operatives".

## THE AGRICULTURAL RESEARCH LABORATORY

### *Start of Mechanized Dairying*

Prompted by Professor Segelcke, N. J. Fjord started research on butter and cheese-making at the beginning of the 1870's. He was the greatest authority on butter production, and when Nielsen invented his centrifugal separator and some doubt was expressed as to the value of this new device, it was Fjord who was requested to test it. His experiments clearly showed that the centrifugal separator gave better skimming, and consequently a higher yield of butter, than any other system. It was from this work that mechanized dairying in Denmark took its start.

1. Then as now Denmark was a country of small farms; 101,500 smallholdings with between 0.6 and 10 hectares of land each, occupied in 1946 only about one-sixth of the total agricultural area (but they accomodated approximately one-half of the total farming population), 102,000 farmers with between 10 and 60 hectares occupied 70 per cent and 4,500 farms, with more than 60 hectares, about 15 per cent of the Danish agricultural land.

### *"Let's ask the Calves and Pigs"*

As more and more dairies installed the Nielsen separator, new critics suggested that there was nevertheless a "snag" about this new machine; they contended that, whereas the skim-milk obtained from tub-skimming was quite good for human consumption and excellent for calves and pigs, the centrifugally-separated milk was of no value whatever, and perhaps even detrimental.

Fjord's reply was: "Let's ask the calves and pigs"—a remark that became the guiding principle of Danish livestock research. Fjord went to four farmers, interested them in the problem, and carried out a series of comparative tests on their farms, proving that the value of the centrifugally-separated milk was very close to that of the tub-skimmed, the only difference being the already established difference in fat content (0.60 : 0.14 per cent). In the case of calves, this meant a difference in daily weight increase of 35 grammes per calf. Those fed with tub-skimmed milk had a daily weight increase of 750 grammes, compared with 715 grammes for those fed with the centrifugally-separated milk. Otherwise no difference was noticed.

### *The Mobile Research Stations*

These experiments led to others with all kinds of food, and Fjord instituted the system of mobile research stations.

Briefly this system, which is still in use, is as follows: all over Denmark there are a number of owners of farms prepared, in the interest of agriculture as a whole, to make their farm buildings and livestock available for research. In many cases these hosts will also make substantial financial sacrifices in order to meet requirements in the way of shed arrangements, etc.

Fjord started with four such research stations; today the Agricultural Research Laboratory has at its disposal 36 stations scattered all over the country. In addition to these there are two government experimental farms, Favrholm and Trollesminde, intended for special research and experiments that would make unreasonable demands on the hosts at the mobile stations.

### *Eradication of Bovine Tuberculosis*

In the course of years the experiments started by Fjord outgrew the framework of the Agricultural College and developed into the system of livestock research as outlined in the accompanying chart.

Formerly a bacteriological department was also incorporated in the Agricultural Research Laboratory, but in order to speed up research and campaigns against contagious diseases, particularly bovine tuberculosis and contagious abortion, it was soon decided to make this department an independent laboratory, the State Veterinary Laboratory. To this laboratory goes much of the credit for the fact that it will not be long before contagious abortion has been eradicated in Denmark—already the first country in the world able to declare all herds 100 per cent free from tuberculosis. In England, only 36 per cent of the herds are free of tuberculosis.

Dairy research was a department within the Agricultural Research Laboratory until 1923, when it was decided to establish a special dairy research laboratory, the Government Experimental Dairy. It might be said

that the stable door forms the demarcation line between the work of the two laboratories: when the milk leaves the stable, the Government Experimental Dairy takes over.

Until recently, livestock research was associated with special research work on semen and insemination methods. This, however, has now been transferred to a newly-established Sterility Research Institute at the Agricultural College. The endocrinological and sex-physiological research of the Livestock and Physiological Department has also been transferred to this new institute, which also has a gynaecological department.

A department for the control of feed-stuffs, set up in 1926 as a subdepartment of the Chemical Department, was transformed into an independent institution directly responsible to the Ministry of Agriculture in 1949.

*Theory and Practice*

It will immediately be seen from the chart on page 36 on livestock research that there is a close connexion between theory and practice. The Government Committee which directs the work consists of representatives of the agricultural organizations, that is, the farmers and smallholders themselves.

What is not revealed by the chart is the close connexion between research and teaching. Though the Research Laboratory is an institution independent of the Agricultural College, most of the scientists at the former give lectures at the latter, thus keeping the students up to date on research developments.

The Government Committee which elects its own chairman—at present the headmaster of an agricultural school—has a budget of 1,500,000 kr. and meets six to eight times a year. To decide on matters of common interest, joint committees are formed by representatives of the Government Committee on Livestock Research and the corresponding bodies in charge of plant culture and dairying research.

*Dissemination of Research Results*

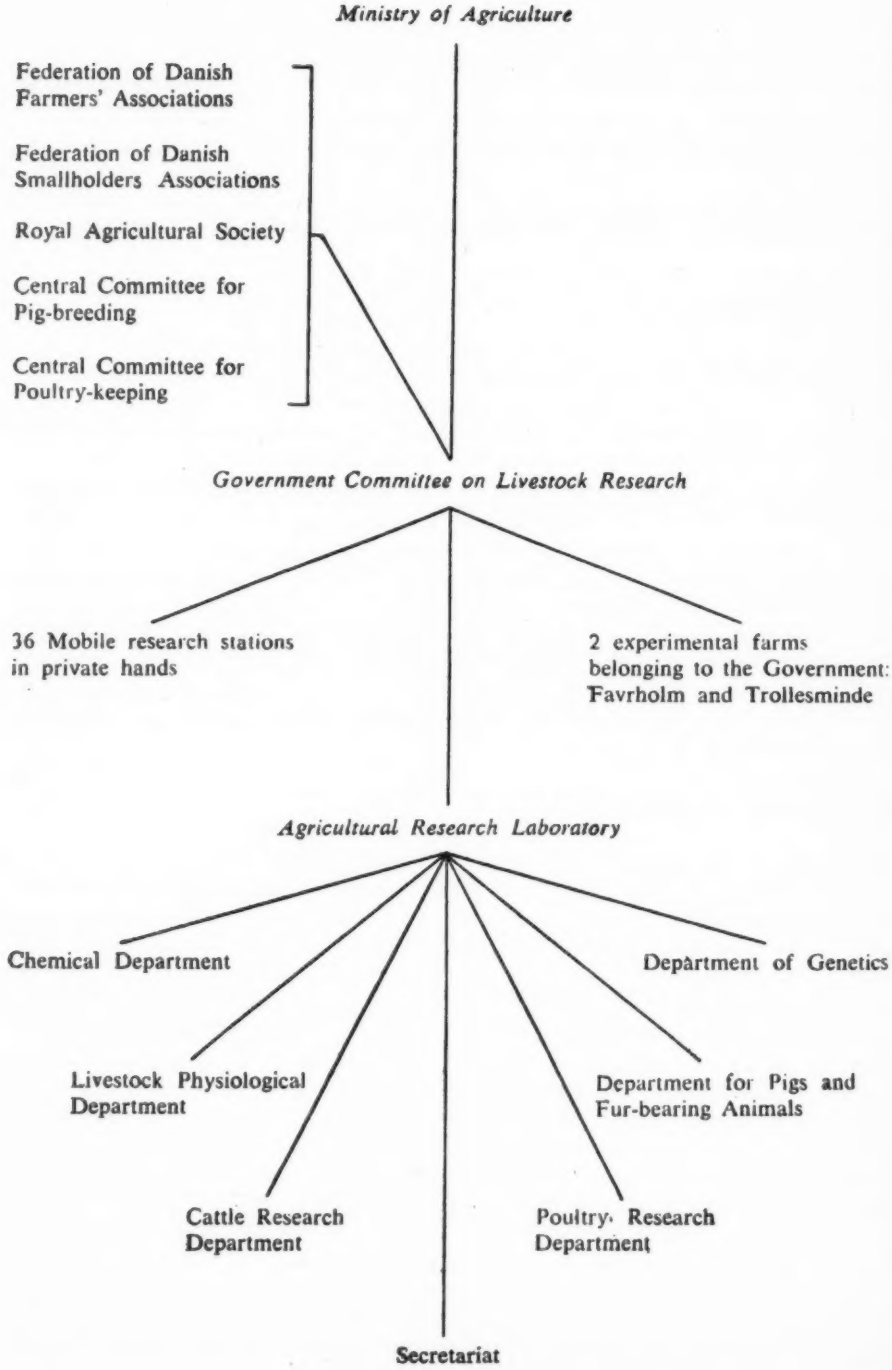
The results of the research are disseminated in various ways.

The members of the Livestock Research Committee report directly to their associations, societies, etc. Reports on all experiments and investigations undertaken are always published by the Agricultural Research Laboratory as soon as the work is completed. They are always widely commented upon in the agricultural press—and Denmark has no less than 85 different agricultural magazines for members of agricultural societies and organizations. The majority of the articles in these magazines are written by agricultural advisers, who also give lectures on the results of the research.

Every year in October the Committee holds a livestock conference to which it invites all advisory officers specializing in livestock husbandry,[1] teachers at all agricultural schools, all chairmen of local livestock committees and organizations, editors of all agricultural magazines, etc.

1. In 1949, of 573 agricultural advisers, 117 specialized in plant breeding, 91 in agricultural accountancy, 84 in domestic economy, 76 in livestock husbandry, 60 in horticulture, 13 in education of young workers, 11 in poultry, 11 in agricultural buildings, 8 in fur-bearing animals, 7 in dairies, 6 in implements and machinery, 5 in milk hygiene, 5 in land improvement, 2 in rabbit breeding and 1 in bee-keeping. The remaining 76 advisers were concerned with more than one of these subjects, usually plant breeding and livestock husbandry together.

## DANISH LIVESTOCK RESEARCH


Ministry of Agriculture
Federation of Danish Farmers' Associations
Federation of Danish Smallholders Associations
Royal Agricultural Society
Central Committee for Pig-breeding
Central Committee for Poultry-keeping
Government Committee on Livestock Research
36 Mobile research stations in private hands
2 experimental farms belonging to the Government: Favrholm and Trollesminde
Agricultural Research Laboratory
Chemical Department
Department of Genetics
Livestock Physiological Department
Department for Pigs and Fur-bearing Animals
Cattle Research Department
Poultry Research Department
Secretariat

At these conferences—usually attended by some 1,000 persons—officers in charge of research describe their work during the past year and everybody present is entitled to speak, criticize, ask questions and propose research on problems encountered in day-to-day work.

Not only the specialized magazines but also some weekly and daily papers devote space throughout the year to the work of the Agricultural Research Laboratory, while news bulletins from the agricultural field form a regular part of the programme of the Danish State Broadcasting Company.

*Information on Developments Abroad*

Thanks to this system of dissemination it is probably in Denmark that new scientific discoveries in livestock husbandry are most quickly applied. By means of State Agricultural Advisers attached to the Danish diplomatic missions, a close watch is kept on developments in the agricultural field abroad, and everything of possible interest to Denmark immediately reported home. All significant advances are immediately made the subject of experiments and tests under Danish conditions, and if found applicable to Denmark, passed on through the dissemination system. One example of this is the Finnish silage method, another the artificial insemination, first applied in Soviet Russia, and now used for about seven per cent of the cows in the U.S.A., 17 per cent in Great Britain and 35 per cent in Denmark.

*Milk Recording Societies*

On the other hand, many methods and ideas from Denmark have found their way to other agricultural countries. To mention just one example: milk recording societies are to be found all over the world today.

The first of these, the Vejen and District Control Society, was formed in 1894. Since then the societies and their membership have continued to increase, and in 1949 there were 1,681 societies with 67,300 members in Denmark. The number of recorded cows was 688,700, about half of the dairy cows in Denmark.

The prime object of the milk recording societies is to ensure the maximum profit from milk production. This is done by regularly examining each cow's food consumption and milk yield and the fat percentage of its milk. It is

Average yield of all Danish cows

| *Accounting year* | *Average per cow* | | | |
|---|---|---|---|---|
| | *Milk* | *Fat* | *Butter* | *Butter fat* |
| | lb. | % | lb. | lb. |
| 1903-04 | 6,850 | 3.40 | 258 | 233 |
| 1913-14 | 7,178 | 3.52 | 281 | 253 |
| 1924-25 | 7,494 | 3.70 | 309 | 277 |
| 1934-35 | 7,729 | 3.80 | 328 | 293 |
| 1937-38 | 8,406 | 3.92 | 369 | 330 |
| 1941-42 (war years) | 6,127 | 4.07 | 279 | 250 |
| 1945-46 | 7,469 | 4.02 | 336 | 301 |
| 1948-49 | 8,164 | 4.07 | 372 | 332 |
| 1949-50 | 8,754 | 4.09 | 401 | 358 |

thus possible to adjust feeding to yield and to know when to eliminate a cow as unprofitable. The milk recording societies have been of great help in raising Danish cattle stocks[1] to their present standard. The improvement in yield due to selecting the best breeding animals and employing increasingly rational feeding methods is best illustrated by the table above.

The milk yield shows a big increase in the past 50 years, and the larger fat percentage obtained has had a marked influence on the volume of butter.

The figures naturally give no indication as to the yield of the best cows. Their annual yield may be about 12,520 lb. of milk an average fat content of 4.48 per cent, i.e. 560 lb. of butter fat corresponding to 631 lb. of butter.

*The Story of a World Record*

In 1947 the Agricultural Research Laboratory carried out, at Stensbygaard, Zealand, a series of experiments with a number of first-class Red Danish dairy cows in order to find out the maximum possible yield when cows are fed and tended under the best possible conditions. The average yield of 10 cows during these experiments was 22,200 lb. of milk of 4.64 per cent fat content (1,031 lb.) of butter fat for a lactation period of 356 days from calving. The biggest yield of a cow in this group (scoring a since-beaten world record) was 25,754 lb. of milk containing 4.62 per cent of fat, i.e. 1,189 lb. of butter fat, corresponding to 1,338 lb. of butter.

The cows were given large, separate stalls in a bright, well-ventilated stable where the temperature was kept constant at 14°-15°C. They were fed four times a day and milked at intervals of exactly six hours. Among the feed-stuffs given were: tepid sugar beet and silage, the beet washed and cut before feeding, the silage of first quality made from young grass and clover with the addition of AIV acid. The hay used was made from early-mown lucerne of good quality. Throughout the experiment an evenly-mixed concentrated feeding-stuff was used, made up of 66 lb. of prepared oil-cake mixture, 31 lb. of coconut cakes, 55 lb. of oats, 24 lb. of sprouted malt, 22 lb. of wheat bran and 22 lb. of molasses feed. The prepared oil-cake mixture consisted of 10 per cent soya bean meal, 25 per cent shelled cotton-seed cake, 20 per cent shelled sunflower cake, 20 per cent coconut cake, 20 per cent linseed cake and 5 per cent molasses.

While the experiment was being carried out with the first class cows from Stensbygaard (where the average yield of the herd under normal conditions was at the rate already quoted for "best cows"), a similar and even more striking experiment was undertaken with six ordinary cows from Wedellsborg at Funen. In the year before the experiment they had averaged 370 lb. of butter fat, but in the year of the experiment, when the cows received first-class tending and as much concentrated food as they would eat (an average of 35 lb. per cow per day, though a few cows consumed as much as 40 lb. of concentrates a day which is more than it was formerly thought possible for cows to eat) the yield rose to 909 lb. of butter fat per cow, that is 150 per cent more than in the previous year. Though much money was spent on concentrated feeding-stuffs, the test cows yielded a handsome extra profit.

1. The total livestock figure usually stands around 3,000,000 head, dairy cattle accounting for half the number. The figure for 1950 was 3,053,000 including 1,577,000 head of dairy cattle. Four breeds are used: Red Danish Dairy, 69 per cent; Black and White Danish, 20 per cent; Shorthorn, 9 per cent; Jersey, 2 per cent.

There is no doubt that many Danish cows would do just as well as the six Wedellsborg cows if scientific farming could be adopted to the fullest extent everywhere. Certain factors, however, prevent this. Having twice in this century (World Wars I and II) been suddenly cut-off from foreign feedstuffs, the tendency in Denmark is to produce and utilize as much Danish fodder as possible.[1] Another difficulty is the question of tending. Correct feeding alone is not sufficient to obtain a very high yield and, under the working conditions that obtain on most Danish farms and smallholdings, it would be difficult to adhere to a régime of milking at exactly six-hour intervals all the year round.

Nevertheless, the experiments have shown Danish farmers that there is still much to be done and that it would be dangerous to be too content with what has already been achieved—however highly foreigners may praise this achievement.

*From the Danish Stable to the British Table*

As already mentioned, dairy research was a department within the Agricultural Research Laboratory until the beginning of the 1920's, when it was decided to establish the Government Experimental Dairy.

A site was selected on land belonging to the two government experimental farms, Favrholm and Trollesminde, run by the Government Committee on Livestock Research.[2] This place was chosen because of the opportunities it offered for close co-operation between dairying and livestock research, and the many experiments carried out to show the effect of different feeding on the quality or dairy products have fully justified its choice.

The task of the Experimental Dairy is to apply science so as to improve constantly the quality of Danish dairy products. This means constant research into the innumerable technical, chemical and microbiological problems of dairying.

In order to keep in touch with day-to-day problems, the Experimental Dairy is not only processing the milk of the state farms at Favrholm and Trollesminde, but also that of the majority of the farms and small-holdings in the district. The results of all experiments are published in special bulletins and an annual report. So far, 70 of these have been published.

*The Story of the "Lur" Brand*

Anybody who has bought Danish butter outside Denmark has probably noticed that it bears the Lur trademark. The story of this brand began when, at a very early stage, the leading Danish dairymen realized the necessity for a high quality of butter. On a completely voluntary basis, they started to hold tests at which butter from different dairies was judged. This gave the dairy managers an opportunity of meeting one another and exchanging information.

1. Whereas only 1,200 farms had silos in 1936, the number in 1950 had risen to 47,300 and a further 27,600 farms, though they had no actual silos, had silage pits.
2. The Government Experimental Dairy is run by the Government Committee on Dairy Research, consisting of representatives from the following organizations: The Danish Dairy Associations, The Danish Dairy Managers' Society, The State Advisory Service (Dairying Experts) and the Agricultural College.

Friendly rivalry grew in intensity and in 1900 a group of dairies formed an association with the object of introducing some system by which all butter of a certain standard would be given a common trademark—the Lur brand. This was registered abroad as the general trademark of Danish butter, and in a very short time it was being used by nearly all Danish dairies. The dairy industry then approached the government with a request that no Danish butter be exported that did not bear the Lur brand. A law passed to this effect in 1906 laid the basis of the testing and inspecting system which is now compulsory for all export butter.

The prescribed butter tests—normally three a year for each dairy—are conducted by a government body whose decisions are final. The butter is also subjected to a variety of laboratory tests with the object of ensuring that a certain maximum content of water is not exceeded. Other laboratory tests are concerned with salt analysis, catalysis test, moisture and mould tests. Should a dairy not conform to the requirements of first class butter, it loses the right to export.

The government tests are supplemented by weekly statutory butter tests and laboratory samplings of butter from all dairies selling for export. The weekly tests take place at the individual export establishments in accordance with prescribed methods. They are a valuable feature of the work done to maintain the quality, as the results are immediately communicated to the dairy management, enabling it to follow the quality of its butter closely from week to week.

To supervise the carrying out of the provisions with regard to weight, packing, etc., there is a special inspection board making unnotified inspections at dairies, butter-exporting establishments, railways and ports.

*Improving the Quality of Bacon*

Turning again to the work of the Agricultural Research Laboratory, a few words must be said of its endeavours to produce pigs of good bacon type, i.e. a long body with lean but not too lean back fat, a thick belly, full hams, etc. A comparison of the half-wild early nineteenth-century pig that

| *Results attesting Stations* | *1926-27* | *1950-51* |
|---|---|---|
| Daily live-weight gain per pig (in grams) | 623 | 667 |
| Food consumption (in food units[1]) per kilogram of live-weight gain | 3.44 | 3.14 |
| Length of body (in centimetres) | 88.9 | 93.2 |
| Thickness of back fat (in centimetres) | 4.05 | 3.40 |
| Thickness of belly (in centimetres) | 3.06 | 3.29 |
| *Marks (0-15) awarded for:* | | |
| Consistency (firmness) of back fat | 12.7 | 13.4 |
| Size of shoulder | — | 12.8 |
| Uniformity of back fat | 12.2 | 12.7 |
| Quality of belly | 12.0 | 13.0 |
| Size and shape of hams | 12.3 | 12.6 |
| Fineness of head, skin and bone | 12.5 | 13.1 |
| Fullness of lean meat | 12.4 | 12.9 |
| General bacon type | 12.4 | 12.5 |

1. One food unit is the feeding value of one kilogram of barley.

roamed loose in the woods and groves living on whatever scanty food it could find, with a modern "streamlined" Danish Landrace pig whose weight can be predicted months ahead[1] gives a real idea of the possibilities of modern science.

Development from 1926 onward can be seen from the table of results at testing stations given above.

*Skim-milk—Key to First Class Bacon*

Feeding experiments on bacon pigs, i.e. pigs weighing 44-198 lb. have been carried out on a large scale since the early 1880's, mainly with bran, sugar beet, maize, potatoes, etc. Many of these aimed at elucidating the influence of various vitamins on health and food-utilizing ability. Guidance in assessing the profitability of a herd has been obtained by calculating from results of experiments the food consumption required for a given production, in terms of live-weight gain and carcass weight. It is useful, also, to know the food consumption needed to produce a given amount of calories. This last point has been very thoroughly investigated by measuring calories in test pigs killed at various weights, and in pigs fed on a normal amount of food compared with others fed on less.

In the days of the great skim-milk controversy, few would have believed that centrifugally-separated milk would one day become a product in great demand, even indispensable for bacon production. That day came in 1920 when pig-keepers began to run short of the skim-milk or whey which, together with coarse grain, constituted the principal food of bacon pigs. It was essential to find foods capable of replacing skim-milk in nutritive value. Although several were found, it soon became apparent that the finest-flavoured bacon could not be produced without a certain amount of skim-milk or whey. The thoroughness, scale and scope of this work are evident from the fact that a recent report on one series of protein concentrates covered 71 experiments on 215 groups, averaging nine pigs to a group, or about 1,900 pigs in all.

As in the case of butter, bacon also is scientifically controlled until it reaches the prospective buyer. This is carried out by the official Bacon Control. The work comprises control of cutting, curing, sorting, packing, transport, etc. The export products of individual factories are controlled at intervals by unannounced "snap" checks at the ports of shipment. In the event of there being any defect in flavour or colour, the bacon is traced back, through the factory concerned, to the producer, in order to obtain particulars of the pig's age and feeding. Where the information so obtained gives reason to suppose that the feeding is directly or indirectly responsible for the defect, the producer is informed accordingly and instructed how to avoid the defect in future.

*Increasing Egg Production*

Turning now to egg production, we find again the Agricultural Research Laboratory—in this case the Poultry Department—increasing the yield

1. With the feeding usual in practical pig-keeping at the moment, it will weigh 198 lb. when six months old.

through experiments on breeding and feeding. Poultry-keeping has been encouraged not only by the associations of farmers and smallholders, but also by special poultry-keeping societies (since 1912 federated in the Society of Danish Poultry Breeders) which have performed an excellent task in promoting egg production. The societies' work includes lectures, study courses, the publication of a membership journal, the distribution of hatching-eggs and breeding-fowls, establishment of breeding stations, the awarding of prizes for flocks, advisory work and poultry shows.

During the 1930's the Ministry of Agriculture appointed two committees: the Government Committee on Poultry Breeding and the Government Committee on Eggs (now amalgamated into the Central Committee for Poultry Breeding). The former committee has especially advocated competitions between whole flocks to facilitate the establishment of breeding centres, cock selection, progeny tests at the Favrholm Control Station for hens, and the publication of an official pedigree book for male birds. The Government Committee on Eggs has taken up educational and propaganda work for improvement in the quantity of eggs.

Both in regard to size and number of eggs, the results have been gratifying. It is estimated that the average egg-laying yield per hen in 1900 was 100 a year, against 165 in 1951. Strict regulations, similar to those for the export of butter and bacon, govern the export of eggs.

*Agricultural Exports*

Butter, bacon and eggs not only made up for the loss of grain exports, but also paved the way for other products. Butter production for instance led to cheese export, export of eggs to export of poultry, etc. Here are some export figures for 1950:

| *Products* | *Millions of kroner* |
|---|---|
| Butter (in casks, boxes, packages, airtight containers) | 906 |
| Live cattle | 257 |
| Cheese | 150 |
| Beef and veal | 39 |
| Bacon and pork | 747 |
| Eggs (fresh) | 324 |
| Dressed poultry | 36 |

To this might be added a steadily-increasing export of condensed milk and milk powder (1950, 99 million kroner; 1951, 128 million kroner), and of canned meat (1950, 148 million kroner; 1951, 289 million kroner). These products, however, together with many others of agricultural origin, are usually considered industrial goods.

## THE STATE EXPERIMENTAL SERVICE IN PLANT CULTURE

While livestock husbandry was developing in Denmark, a substantial increase took place in the annual harvest. In terms of crop units, it is now three and one-half times as high as in 1880.

Much of the credit for this belongs to the State Experimental Service in Plant Culture. The preliminary work for the establishment of this service was performed by P. Nielsen, a pioneer in many fields ranging from investigations of plant diseases to experiments with manure. Like Fjord, he began his career as a village school teacher. In the 1870's, working on the school allotment and at various farms in the neighbourhood, he began making a thorough and extensive series of investigations on the plant populations of pastures. The Royal Agricultural Society became interested and helped him financially until the State took over and appointed Nielsen leader of the State Experimental Service in Plant Culture which today has 18 experimental stations and sub-stations spread all over the country, including five concentrating on gardening and fruit-growing research. This service also includes: the State Experiment for Plant Pathology, comprising a botanical and a zoological department; the State Laboratory for Plant Culture, comprising a department of agricultural chemistry, a department of bacteriology and a department of soil chemistry; the State Experiment in Weed Eradication; and the State Experiment in Apiculture, which deals with the influence of bees on plant production and, since April 1945, also includes diagnosis and control of contagious bee diseases.

Since the death of Nielsen, the administration of the entire research work has been in the hands of the State Board of Plant Culture, consisting of representatives of the Federation of Danish Agricultural Associations, the Federation of Danish Smallholders' Association, the Danish Horticultural Societies, the Agricultural College, and the Royal Agricultural Society.

Results of research undertaken are announced and discussed at the annual meetings of the State Board and published in special reports and bulletins. They are usually followed up by local experiments (about 2,500-3,000 experiments a year) carried out for the Agricultural and Smallholders' Associations by the agricultural advisers. In addition, several private enterprises such as seed firms and sugar factories have their own experimental stations, concentrating mainly on plant breeding.

### *Some Results of Plant Research*

The table below gives recent figures from Denmark and (for comparison) some other countries.

Harvest yield (in quintals per hectare) in 1949

| | *Wheat* | *Rye* | *Barley* | *Oats* |
|---|---|---|---|---|
| Denmark | 36.0 | 24.1 | 34.6 | 31.9 |
| France | 18.9 | 12.1 | 16.1 | 13.2 |
| U.K. | 27.3 | 20.8 | 24.9 | 21.9 |
| U.S.A. | 10.0 | 7.5 | 13.0 | 11.7 |

The average annual grain harvest, in quintals (100 kg.) per hectare, in Denmark in 1880-84 was: wheat, 21; rye, 17; barley, 17; oats, 14.

In order to make the best use of imported concentrated feeding-stuffs, such as oil cakes and coarse grain, it was found necessary to supplement them with coarse animal feed (root crops and grass). The production of coarse feed accounts today for approximately 55 per cent of the total agricultural area. Grassland now yields 15 crop units more per hectare or a total of 17 million crop units per year more than in 1925. This is partly due to the introduction of a new Danish strain of red clover which yields 25 per cent more than those previously used—all imported.

*One-quarter of a Millimetre of a Bee's Tongue*

While seeking for a higher-yielding strain, the plant-breeders at the same time looked for one with a short corolla tube, as it had been found that the red clover would seldom seed because the only insect capable of pollinating it was the bumble-bee, then on the decrease in Denmark. The tongue of the honey bees was too short. The breeders succeeded in finding a higher yielding strain with a shorter corolla tube, but it was still one-quarter of a millimetre too long for the honey-bee. The possibility of acquiring an area in Poland where bumble-bees abounded was considered, but thanks to the apiculturists, this was avoided. By studying the tongues of various bees under the microscope, the apiculturists found that Italian bees had a tongue one-quarter of a millimetre longer than the Danish bee, and the problem was solved by importing Italian bees to Denmark. Today Denmark is able to export seed of red clover. Total seed exports in 1950 were: seeds of red clover, 4 million kroner; seeds of other clovers and other pulses, 13 million; grass seeds, 52 million; root crop seeds, 4 million; horticultural seeds, 7 million.

This is no mean record for the plant breeders who have also achieved such noteworthy results as the Kenya and Maja strains of barley. In Denmark alone, these have increased the annual value of the harvest by 40-50 million kroner.

As a result of scientific breeding, better cultivation and fertilizing, the sugar output per acre of sugar-beet is now 10 times as high as when the first Danish sugar-beet factory was built in 1802. In 1924 the sugar-beet harvest per hectare was 24.3 tons. The figures now are:

| | *Tons per hectare* | | *Sugar* |
|---|---|---|---|
| | *Root* | *Top* | *%* |
| Maribo N | 45.0 | 33.9 | 17.3 |
| Maribo T | 46.7 | 34.3 | 16.9 |
| Maribo P | 47.6 | 36.5 | 17.2 |

The surplus sugar-production is exported (export of sugar and molasses in 1950: 120 million kroner). In recent years potatoes have also helped to improve the Danish balance of trade. In 1950 seed potatoes to a value of 17 million kroner and other potatoes to a value 13 million kroner were exported. Apples to a value of 17 million kroner, and jams, marmalades and fruit juices to a value of 10 million kroner were also exported in the same year.

## DANISH INDUSTRY

### *The Interdependence of Agricultural and Industry*

Total export of agricultural products in 1950 amounted to 2,825 million kroner, of industrial goods 1,537, of fish 120, and of other goods 72 million kroner. In 1951 agricultural exports leapt to 3,300 and industrial to 2,237 million kroner.

As has already been said, many industrial goods are of agricultural origin, from canned meat and condensed milk to sugar, fruit juices etc.[1] Industry is profiting from agriculture, and vice versa. Modern Danish dairying was started when Nielsen invented the centrifugal separator. But it is difficult to decide whether it was the dairies which influenced the production of Danish dairy machinery, or whether it was the machinery manufacturers who promoted the introduction of new processes. Suffice it to say that, with the Agricultural Research Laboratory and—later on—the Government Experimental Dairy as the catalyzing agent, Danish dairies are using machinery that is constantly being modernized by a branch of Danish industry which not only covers the home market, but has also a considerable export of separators, pasteurizers, butterworkers, milk pumps, homogenizers, etc.

The Danish refrigerating industry developed in response to the needs of the dairies and bacon factories. In 1902 a Danish firm delivered a refrigerating plant to the first Danish cold-storage ship—a steamer used for shipping butter to England. So began what was to develop (in recent years with the help of the Danish Low-Temperature Research Station) into a Danish speciality. Today, two of the world's three largest suppliers of marine refrigerating plants are Danish firms. They produce not only the usual plants for use on ships carrying frozen or chilled meat, butter, etc., but also equipment for refrigerating cargoes of all kinds of fruit. Fishing vessels are fitted with plants for freezing or cooling their catch before landing it.

### *The Interdependence of Industry and Fishery*

Danish fishery, after having occupied a prominent position for centuries—herring was one of the main exports of Denmark—gradually declined during the seventeenth and eighteenth centuries and had almost disappeared by the beginning of the nineteenth century. It was carried on only as a sideline by smallholders living near the coast, almost exclusively by means of open boats, haddock boats for catching whiting, and the smaller sculler boats for plaice. The invention of the seine by the Danish fisherman Jens Vaever in the 1870's was the first step towards the revival of Danish fishery. The heavy open rowing boats were replaced by lighter sailing vessels, the open boats by deck boats, and fishing began outside coastal waters. It was not, however, until the motorization of the fishing fleet began in the 1890's that Danish

1. Even the pharmaceutical products industry, which in 1951 had an export to the value of 70 million kroner, grew up in collaboration with agriculture. The bacon factories provided the glands for its first export article: insulin. Suprarenal glands and parathyroid hormones followed, and later came liver and ventricle preparations, and sex hormones. Quite independently of the Allies, Danish scientists started during the war the production of penicillin. In addition, other antibiotics are exported.

fishery started to regain its importance. The refrigerating industry began to take an interest in fishery, and the Technological Laboratory of the Ministry of Fisheries provided the scientific background for the canning of fish. Exports of canned fish, which were 26 million kroner in 1950, are gradually rising.

While experimenting with boats and engines for Danish fishermen, Danish boat-builders and engine-constructors also developed types suitable for fishermen in other countries—and thus a new Danish export industry was born. Today Danish engines for cutters, trawlers and fishing-vessels are to be found all over the world (41 per cent of the diesel-driven French trawlers have engines of Danish construction).

*Danish Diesel Engines*

But it is not only trawlers that have been fitted with Danish diesel engines—nearly 50 per cent of all motor ships in the world are equipped with diesel engines either built in Denmark or under licence from Denmark.

Diesel was not a Dane, but like Danish agriculturists, Danish industrialists were always on the lookout for new methods and inventions. And on 28 January 1898, a contract was signed between Rudolf Diesel and the director of the Danish firm Burmeister and Wain (B and W) under which the firm was licensed to build diesel engines in Denmark and acquired the right to patent all improvements it might be able to make.

The first diesel engines built in Denmark were stationary, but B and W soon began experimenting with diesel engines for the propulsion of large ships. Rudolf Diesel doubted that his invention could be used for this purpose, but on 18 January 1912, the first large sea-going ship driven by diesel engines went on trial from the yard of B and W. The ship was the Selandia, built for the East Asiatic Company of Copenhagen, of 4,964 gross register tons, and had two B and W diesel engines developing together 2,500 h.p. The ship stood the test and completed her maiden voyage to Bangkok and back. Thus H. N. Andersen, head and founder of the East Asiatic Company, and Ivar Knudsen, managing director of B and W, inaugurated together a new and far-reaching development in world shipping.

The B and W engine, the first fully developed marine diesel engine, has known many competitors during the past 40 years but by constantly improving and producing new types, Danish technicians have been able to maintain their lead. Thanks to the good start gained by Danish yards, shipbuilding in the inter-war period developed into an important Danish export industry, though Danish delivery of ships to the world market is small in comparison with the number of Danish marine engines in use. In the years 1937 and 1938, the Danish output of ships was in the regions of 200,000 tons per year, of which about 85 per cent and 65 per cent respectively were exported. Since the end of the war the Danish ship-building industry has worked mainly to replace the tonnage lost by Danish owners during the war—roughly 500,000 tons—but nevertheless is was able to export eight ships totalling 47,550 GRT in 1951.

*Engineers as an Export Article*

The industrial development outlined above would hardly have been possible if Denmark had not had at its disposal a staff of well-trained engineers and a sufficient number of highly-skilled workers. In contrast to many other countries, Denmark has retained the old institution of apprenticeship and much attention is paid to technical training (for details of technical education and training in Denmark, see Appendix I).

That the education offered at the Technical College conforms to international standards is apparent from the fact that, of the 5,525 engineers of all categories who graduated from the college since its establishment in 1829, no less than one-third worked for varying periods abroad, most of them since the last decades of the nineteenth century. Before that time, in a period when technical developments like railways, gasworks, waterworks, etc., were spreading to Denmark, Danish engineering was practically of no importance, the country having to rely mainly on British engineers. In 1870, however, a Danish firm of contractors completed a railway project in Sweden, and from then onwards Danish engineering gradually turned into an export commodity.

*Civil Engineering*

Towards the end of the nineteenth century, a series of patents was taken out, mainly by France, for a special form of concrete construction reinforced with iron rods. This laid the foundation of an entirely new building-material, ferro-concrete, which revolutionized building technique. By a fortunate coincidence, the Technical College had at that time, as its professor of technical statics, an outstanding personality in A. Ostenfeld. Not only did he make an all-important contribution to the development of the entire theoretical basis of his subjet, but he also stimulated his students to take a keen interest in the problems of statics and their solution. This was of vital importance to a whole generation of Danish civil engineers, who subsequently made substantial pioneering contributions in various fields of ferro-concrete technique, especially in hydraulic structure.

All over the world Danish-built harbours, bridges, railways lines (such as the Trans-Iranian Railway from the Caspian Sea via Teheran to the Persian Gulf) are to be seen—and Danish cement is to be found everywhere.

Amongst the very few raw materials available in Denmark are some of those necessary for cement production, deposits of fine chalk and stoneless moraine clay being readily accessible in certain parts of the country. To the export of cement, Denmark has added the export of cement-making machinery. Most of the progress in the technique of cement making is due to the firm which owns and operates the largest cement factories, one of which is the biggest in the world. This firm's deliveries of machines for cement factories—including everything from revolving kilns to modern flux-packing machines—account for one-third of the world's present production of cement. Danish machines are to be found in as many as 1,000 of the world's cement factories.

*The Standard of Living*

Thanks to its constantly-growing income from exports, Denmark now enjoys one of the highest standards of living in the world. Social differences are not so marked as in many other countries. Industrial and trading capital is fairly evenly distributed both in agriculture and in industry. The majority of industrial (as well as agricultural) establishments are of small or medium size: according to the 1948 census, the largest group of industrial enterprises (10,612) had an average of one to five workers, the establishments with more than 100 workers formed the smallest group numbering 56 firms.

Of the urban dwellers 44.8 per cent have apartments consisting of one-two rooms plus kitchen, 43.7 per cent have three-four rooms plus kitchen, 9.1 per cent five-six rooms and 2.4 per cent seven or more rooms; 89.6 per cent of the apartments are equipped with gas, 99 per cent with electricity and 35.4 per cent with bath. About half of the households in Denmark have a telephone and practically every one a wireless set. Furthermore, every household reads one and one-quarter newspapers a day. As a consequence of progress in medicine and hygiene due to its increasing prosperity, Denmark is now among the countries with the lowest mortality rate. This has dropped from an annual average of 18.5 per thousand inhabitants in 1881-90 to 9.2 in 1950. Life expectancy at birth in the period 1901-5 was 52.9 years (men) and 56.2 years (women). In the period 1941-45 it was 65.6 (men) and 67.7 (women).

Another feature of the increasing prosperity is the growth in physical stature from 166 cm. in the years 1879-88 to 175.4 cm. in 1950, recorded at the annual enlistment of army recruits.

Social legislation has steadily widened during the present century so that, generally speaking, Denmark now ranks among the most socially-advanced countries. The more than 40 laws on social insurance and public relief in existence in 1933 were, in that year, codified in the Social Reform Act comprising four laws, the Public Relief Act, the National Insurance Act, the Workmen's Compensation Act, and the Labour Exchanges and Unemployment Insurance Act.

A recent feature of Danish social legislation is the allowance of rental rebates for large families where financial circumstances warrant it. Other new laws passed since 1933 comprise the Holiday Act of 1938 extending the legal right to holidays with pay to all wage-earners and salaried employees, the Act of March 1939 on the establishment of public Maternity Aid centres, the Act of July 1948 prescribing free milk for expectant mothers, and the Home Help Service Act of 1949 making it possible for private homes to obtain free home help during periods of illness, convalescence, etc.

This high standard of living is due in a large measure to exports, but to some extent it has itself promoted exports. The rise in the productivity of workers during this century is not due solely to improved standards of professional training, but also to better general social conditions. Of course, the existence of a large and exacting home market—due to the high standard of living—has greatly stimulated exports. Radio equipment and electric power cable are examples in point. In the case of the latter, all the raw materials have to be imported—copper from America or Africa, lead from Mexico, steel from Belgium or France, paper from Sweden, Norway and

Finland, jute from India, asphalt from France, impregnating oils and fuels from the United States and Great Britain. Yet without protective tariffs, and with the world's two largest cable-exporting countries, Britain and Germany, as its neighbours, Denmark nevertheless succeeded in building up an export in this field, simply because the Danes have a home consumption of electricity corresponding to the needs of 10-15 million people and not merely to the four million which form the population of Denmark.

But part of the credit is due to Denmark's scientific achievements. In 1902, Krarup invented the continuously-loaded cable, making long-distance telephony possible via submarine cables. In 1903, Valdemar Poulsen invented the electric arc generator making wireless telegraphy possible.

## ORGANIZATION OF SCIENCE IN DENMARK

Danish science is basically state-financed. Its backbone is the University of Copenhagen, founded in 1479, a public institution directed by the Ministry of Education. It has five faculties: Theology, Law and Economics, Medicine, Arts, Science. The number of registered students is about 6,500.

The University of Aarhus, founded in 1928, is a private institution supported by the state. It has four faculties: Arts, Medicine, Law and Economics, and Theology. The number of students registered is about 1,500.

Most of the money spent by the state on these institutions, on the colleges already mentioned (the Technical and Agricultural Colleges), and on the Pharmaceutical and Odontological Colleges was for teaching purposes and applied science. Most of the money for fundamental research came from the private Carlsberg Foundation (see Appendix II).

This tendency to favour applied science—where quick results were to be expected—to the detriment of fundamental science gave rise to criticism. A private committee of scientists was formed, and the matter brought up for discussion in Parliament. The recommendations of the privately-formed committee were passed on to the official committee established as a result of the debate in Parliament. Some improvements have since been made. For example, a Science foundation to which the state contributes two million kroner a year for the promotion of fundamental research has been set up, and the salaries of the scientists have been somewhat increased. A daily paper established a science prize of 10,000 kroner tax free to be given every to a promising young scientist, and this example has been followed by several private institutions, some of which give annual prizes of up to 50,000 kroner.

Thanks to the discussions promoted by scientists and science writers, there is a growing awareness in Denmark of the vital part science has played in the economic and social development of the country and of its potentialities for the future. On the whole, the position of fundamental science in Denmark is today healthier than it was 10 to 15 years ago.

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A list of Danish technical books and articles in the main languages may be obtained from the Library, The Technical College, Copenhagen.

## APPENDIX I

### *Technical Education and Training in Denmark*

The Technical College, founded in 1829, is a public institution under the supervision of the Ministry of Education. The number of students is about 2,100. It has four branches of study: Chemical Engineering, Mechanical Engineering (including Shipbuilding), Civil and Structural Engineering, and Electrical Engineering. The duration of the courses of study is fixed at four and a half to five and a half years, but may be extended to six and a half to seven years. The degree of Master of Science (Civilingenior, cand. polyt) is awarded.

A number of technical institutes in Copenhagen and the larger towns give technical training of an advanced standard for artisans in the building, electrical, mechanical, and shipbuilding trades. They last from two and a half to four years. The successful students of some of these courses qualify for an engineering diploma. In 1949 there were 10 such institutes, with a total of 2,500 students.

The Technological Institute, Copenhagen, was founded in 1906. It renders technical service to Danish crafts and industries by arranging educational courses, by giving advice, and by conducting experiments and technical research. Educational work, intended for masters and journeymen, takes place at day and evening courses in Copenhagen and at special travelling courses all over the country. It comprises practical workshop work, with the required supplementary theoretical instruction and advanced theoretical training.

The advisory service and the experimental work are carried out from the Institute's 20 specialized departments.

The number of students in 1948-49 was 18,501 with an aggregate attendance of 1,303,710 hours. Advice was given in 21,418 cases.

The Technological Institute, Aarhus, founded in 1943, is performing a task similar to that of the Institute in Copenhagen, though on a smaller scale.

Practically all technical education in Denmark, with the exception of that given by the Technical College, is based on a four-five years' apprenticeship in one of the skilled trades with a master or an industrial concern, and the passing of a journeyman's test as prescribed by the Apprenticeship Act of 1937.

Some 365 technical schools and trade schools in the cities, towns and rural districts provide theoretical and practical courses for apprentices, mostly in the evening, to supplement their practical training with the masters; in 1949, these courses were attended by about 47,000 students.

A special type of technical boarding school has developed in rural districts and provides courses of an elementary and advanced technical standard, especially for the building trades. In 1949 there were 10 such schools with about 1,000 students.

## APPENDIX II

### *The Carlsberg Foundation*

The largest scientific institution of its kind in Scandinavia has one unique feature: directed by scientists, it owns and operates an industry. In this it perpetuates the work of its founder, J. C. Jacobsen (1811-87) in his dual capacity of brewer and benefactor of science. An ardent admirer of the Danish physicist H. C. Oersted, the discoverer of electromagnetism, who founded the Technical College, he not only

established the Carlsberg Laboratory, but also the Carlsberg Foundation, and even left his home for the use of a distinguished Danish scientist (at present occupied by the Danish Nobel Prize Winner, Niels Bohr).

The Carlsberg Laboratory has a physiological and a chemical branch, the character of research being left entirely to the scientists in charge.

First director of the physiological branch was Emil Christian Hansen whose introduction of pure yeast was a pioneer achievement. His successor was Johannes Schmidt, best known as leader of important marine investigations in which he discovered the migration of the eel. The present director, Ojvind Winge, has revealed that yeast, under certain conditions, will reproduce sexually.

First director of the chemical branch was Johan Kjeldahl, known for his method of determining nitrogen in organic substances. He was succeeded by S. P. L. Sorensen who did research work on the properties of albumins and enzymes. He is known to the chemists all over the world for his "pH", the term given by him to denote the degree of acidity or alkalinity of a solution. The present director, K. Linderstrom-Lang, has continued Sorensen's work on albumins and has conducted important research into the distribution of enzymes in cellular tissue and in individual cells.

To the Carlsberg Foundation Jacobsen first donated a sum of 1 million kroner and shortly afterwards also bequeathed to it the Old Carlsberg Brewery. The Foundation was extended by his son with the endowment of the New Carlsberg Brewery. The Breweries are run by the Foundation which is associated with the Royal Danish Academy of Science. Part of the profits of the New Carlsberg Brewery goes to an art foundation, but most (about two million kroner annually) goes to the maintenance of the Carlsberg Laboratory (plus the Carlsberg Foundation Biological Institute, founded in 1932) and for the general promotion of Danish science, especially fundamental science.

# BOOKS AND PUBLICATIONS

THE ATOM STORY,
by J. G. Feinberg, with illustrations by Lewis and a foreword by Frederick Soddy, F.R.S., Allan Wingate, London, 1952, 243 pp., 15s.

We have embarked upon the atomic age, and it is important that as many people as possible should know something of the chain of events which led to the liberation of nuclear energy. Attempts to tell the story of the atom have not been lacking since 1945, but very few of them have succeeded in telling the story so as to attract the uninitiated average reader. In this respect, Dr. Feinberg certainly succeeds better than most. He starts at the beginning, with Democritus in the fifth century B.C., and ends with the hydrogen bomb of 1952. The scientific facts are set down simply and intelligibly in a manner which, on the whole, does credit to the art of popular science writing. It is therefore a pity that the author should have thought it necessary to brighten his book with occasional facetious passages which detract both from the subject and an otherwise simple and attractive way of writing.

The book is true to its title—it sets down undeviatingly the story of the atom. Beyond touching upon the broad potentialities of atomic energy as a source of power, as an aid to medical and scientific research and as a weapon of destruction, it does not make any serious attempt at evaluating the social aspects of the subject. But this, it is true, would have necessitated a volume in itself.

"SCIENCE IN THE SMALL FIRM",
by A. King, *Research,* Butterworth, London, October 1952, pp. 464-68.

There is no single explanation for the difference in the level of productivity in Great Britain and the United States, but two significant facts emerge from the numerous discussions and studies undertaken on the subject: first, that there are apparently limitless possibilities for industrial improvement in Britain and, secondly, that the predominant factor in the long run will be the strength of the current new developments such as better production techniques, new methods and processes, improved machinery and plant, all of them in their turn backed by scientific research. The problem is, therefore, how to speed up the application of science in industry, particularly in the small firms which account for a very substantial proportion of British industry and which have not the means to apply new scientific information, still less to acquire it by research.

The Research Association system (which is a co-operative research scheme) and the sponsored research institutes (highly-organized consultants who carry out research or development work by contract) may be a partial

solution to the problem of helping small firms on the scientific plane, but it would seem that it is the large and medium-sized firms which profit most by such methods. Yet there is a tremendous reserve of unused scientific information whose very existence is unnoticed by most of the firms, large and small. Furthermore, many of the scientific improvements and new industrial techniques capable of immediate application are not patentable monopolies, and are consequently available to industry as a whole. The use of a large number of such small improvements can make a great difference to industrial efficiency. It is therefore worth inquiring how such new scientific knowledge can be made available with a view to its early application.

Publication of results of research in the technical press or by means of monographs and brochures is not a satisfactory method, for it is mostly understood by firms already well-based on science, while those with limited technical facilities do not even read it. The very style in which such work is generally reported is repellant to non-scientific people and even to scientifically-trained people who are not specialists in the subject. Much thought will, therefore, have to be given to new and improved methods of dissemination. The technique of writing selectively for particular kinds of reader is not yet completely evolved, but its possibilities are so great as to demand urgent action.

An alternative method of disseminating knowledge is by means of a technical information service. This may take many different forms, ranging from a library service to a specialized information bureau. In Britain there are altogether some 60 specialized information services catering for particular branches of industry, and their influence in speeding technical innovation is substantial. They are operated in a decentralized manner by specialist information officers attached to centres of research and development. Within the DSIR there is a strong information section which acts in many ways as the centre of this network. However, the success of an information service is determined largely by the quality of the scientists who operate it, and in this respect, the position is far from satisfactory.

Another means capable of improving considerably the efficiency of small firms is operational research—and simple operational studies are within the scope of any intelligent management. Moreover, operational research could prove valuable in dealing with human problems and needs which are no less important than technical shortcomings in determining the level of productivity.

"THINK ON THESE THINGS",
editorial commentary, *Research,* Butterworth, London, September 1952, pp. 397-98 and October 1952, pp. 445-48.

This series of two articles is devoted to a discussion of some ways in which Britain's economic difficulties might be solved, particularly the contribution which the appropriate use of science and technology could make towards improving Britain's balance of payments. For the basic assumption of this discussion is the argument that lack of interest of scientists in economic problems, and ignorance of politicians of the possibilities offered by science and technology, have contributed much to Britain's economic difficulties.

In the past, Britain had the great advantage of being first in the industrial field. This meant not only that British manufactured goods could compete almost anywhere with hand-made local goods, but also that British inventions, British engineers and British development schemes earned revenue all over the world. For the overseas investments, which were earning large sums of money every year and were contributing in no small measure to the equilibrium of the balance of payments until many of them had to be sold during the 1939-45 war, were in large measure the result of British engineering prowess. It was to a large extent by her ideas and inventions, and by the skill of her engineers that Britain became the rich industrial nation of the nineteenth century; though this success also required business men and financiers with courage and foresight enough to invest money in revolutionary new methods and processes, and a government which did not discourage industry from taking such risks.

Today the story is quite different. Heavy taxes on industry and controls of all kinds make it difficult for new methods to be developed. Moreover, long years of successful trading have replaced the industrialist with bright ideas and scientific or engineering training by the industrialist with accountancy or financial training. Finally, other countries have learned to use machinery, and, as a result, Britain can no longer expect to pay her way with her former traditional exports. She cannot have a thriving cotton industry unless her designs are better than those of her competitors. In other words, to succeed, she must, as in the nineteenth century, export ideas.

Increased productivity, in spite of its undenied importance, is not the answer to Britain's problem. The answer lies not in how much to produce, but what to produce. Countries like Britain, which have to import raw materials, should concentrate on exports which have a high conversion rate, i.e. products whose value is greatly superior to that of the raw materials needed for their manufacture. Watches, for example, are worth about £100,000 for every ton of raw material used, for their sale price is made up largely of the wages of skilled hands, capital charges on precision machinery and repayments on the ideas and ingenuity that made the machines possible. Even better money-earners abroad are exportable processes which may be operated under licence and which earn royalties without increasing the bill for imports. For that, Britain, once the workshop of the world, will have to make herself the laboratory of the world. She must ensure that the shocking story of the manufacture of penicillin is not repeated; that her lead in the design of jet air-liners is not lost; that inventions do not lie unheeded on a dusty shelf because no further capital expenditure can be allowed for their development. Nor can new ideas be developed for export only. For who would buy the most modern gas turbine locomotive from a country whose own railway system was years out of date?

One of the factors hampering the development of British industry along modern lines is the fact that most policy-making executives in industry have no scientific or technical background. A survey of the background and history of 1,173 directors of larger public companies (with shareholders' net assets of £1 million or more) reveals that only seven per cent have had a scientific training. For industry as a whole this percentage would be very much smaller. In short, at policy-making level there is a lack of technical knowledge in industry. But there is also the hampering effect of taxes and government controls.

The solution of Britain's economic problem lies in correcting the deficiencies and eliminating the obstacles described. The number of firms which are able to take part in any plan for development and research work is limited by the high cost of industrial research. Therefore government help in one form or another might have to be given to projects which are economically desirable. As for the choice of the projects, a possible solution might lie in the appointment of a committee drawn from economists, government, scientists and technologists, which would examine, in the light of scientific knowledge and economic necessities, which projects should be scheduled for development. What is required now is a change from the policy of random exports to one more in keeping with the country's scientific and technological potentialities and economic necessities.

## "THE ERADICATION OF MALARIA",
by Paul F. Russell, *Scientific American,* June 1952, pp. 22-25.

For 2,000 years malaria had made the Holy City of Rome notorious throughout Christendom as a fever spot. It continued to plague Italy right into the twentieth century and 50 years ago it was still killing 8,000 to 10,000 victims each year. As recently as 1945 there were 411,600 malaria cases in Italy, though the death toll, thanks to atebrin, had been reduced to 386. Now, in a few years, Italy has utterly routed the pestilence. During the first half of 1951 there were only 392 cases of malaria, and not a single death from the disease has been reported in the past three years. In the ill-famed Pontine Marshes, whose fertile land was uninhabited for 20 centuries because of the dread of malaria, today more than 100,000 people live in health and prosperity.

Italy is a model of what can be accomplished with mankind's new weapon against malaria: DDT and such related insecticides as benzene hexachloride. These destroyers of malaria-carrying mosquitoes have made it economically feasible to eradicate malaria from a whole nation, instead of merely trying to control it in a limited area. Because they remain lethal to mosquitoes for many months, they make it possible to wrest a region from the insects and hold it against reinvasion.

Italy's fight against malaria started in the early thirties. A many-sided effort—draining the swamps, killing mosquito larvae with Paris green, screening houses, distributing quinine—succeeded in reducing the number of malaria cases in Italy to 55,000 in 1939. But the measures were expensive, and not practicable in every province. During the war they were largely dropped and the number of cases rose again to 400,000. But the war also launched DDT as a weapon against malaria. The Malaria Branch of the Allied Control Commission did some experiments which showed that the disease could be effectively and cheaply controlled by spraying houses with DDT solutions. At the end of the war Albert Missiroli, Italy's leading malarialogist, formulated a five-year plan according to which the ceilings and inside walls of every house and animal shelter in every malarious area of Italy were to be sprayed once a year, just before the malaria season. This plan was successfully carried out at a cost of approximately 50 cents *per capita* per year.

Sardinia was made the object of a special test to find out whether it was

feasible to eradicate the malaria mosquito completely from a region where it had been at home for centuries. After five years Sardinia, formerly one of the most severely-afflicted regions in the world, was entirely free of malaria, although the malaria-carrying mosquito escaped annihilation. It would thus seem that it is not practicable or necessary to try to eradicate the mosquitoes entirely, but malaria can be controlled adequately by spraying houses.

Similar campaigns have been carried out in Ceylon, in Bombay State, in Venezuela, in Brazil, in British Guiana, in Greece, and elsewhere, and the results of the past few years have been spectacular. Yet on a world scale the battle is only just beginning. In the malarial regions of Asia, the Near East and Equatorial Africa, the Anopheles mosquitoes this year will infect some 300 million people, of which about three million will die. Now malaria has a huge impact on the world's economy and politics. It is a major cause of poverty and malnutrition, and therefore of unrest, in the backward regions. It cuts heavily into the production of some of the world's key materials, such as rubber, minerals, spices, oils, hardwoods, etc., increasing the cost of these items by something like five per cent. Finally, it limits the afflicted peoples' buying power and progress toward industrialization. Strong support for continued research and for the fight against malaria is therefore of vital interest even to the countries which have eradicated the disease.